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SCIENCE EDUCATION

HERBERT ANDREW SMITH

VOLUME 45 DECEMBER, 1961 NUMBER 5

SCIENCE EDUCATION

THE OFFICIAL ORGAN OF

National Association for Research in Science Teaching
Council for Elementary Science International
Association on the Education of Teachers in Science

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University of Tampa
Tampa, Florida

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SCIENCE EDUCATION

VOLUME 45 DECEMBER, 1961 NUMBER 5

HERBERT ANDREW SMITH

Professor Herbert Andrew Smith is serving as the twenty-ninth president of the National Association for Research in Science Teaching. He will preside at the annual meeting of the Association to be held in Washington, D. C., on February 21–24, 1962. As has been the custom, he is made recipient of the Twenty-Eighth Science Education Recognition Award. President Smith continues the long line of outstanding leaders in American science education who have guided the destinies of this distinguished organization. His tenure of office seems destined to be remembered as the most momentous in the history of the National Association for Research in Science Teaching, with the possible exception of its first president, W. L. Eikenberry. Fate may have cast him as playing the leading role in the decisions relating to the welfare of science education in the last half of the Twentieth Century.

Professor Herbert Andrew Smith was born in Clatonia, Nebraska, April 7, 1916, the son of Chester W. and Verna B. (Heckman) Smith. His paternal grandfather came from England and homesteaded in Greeley County, Nebraska. The date of the arrival of his mother's family in America is unknown. His great grandfather fought in the Civil War with the Confederacy. Professor Smith has a brother Melvin living in Shreveport, Louisiana; and four sisters: Hilma, Dallas, Texas; Georgia, San Jose, California; Wauneta, Sacremento, California; and Ileene, Cortland, Nebraska.

Doctor Smith married Hilda Helen Holz daughter of Mr. and Mrs. Albert Holz, at Pickerell, Nebraska, August 21, 1938. They are the parents of four children: Marla (deceased); Sandra Kay born April 7, 1941; Barry Wilfred, born November 24, 1942; and Cynthia Lynn, born March 25, 1949. The Smiths are members of the Presbyterian Church.

Doctor Smith began his education in a one-room rural school—District 50 in Gage County, Nebraska. He graduated from the Clatonia High School in 1934. He entered the University of Nebraska in 1934 and received a B.Sc. degree in Education in 1938. An M.A. degree from the University of Nebraska was received in 1941. He did graduate work at the University of California in 1947. A Ph.D. degree from the University of Nebraska was awarded in 1948.

Teaching experience includes:

Science Teacher and Principal, Burr, Nebraska, '38–'40
Head of Science Department, Wayne, Nebraska, '40–'42
Science Teacher, Fremont, Nebraska, '42
Superintendent of Schools, West Point, Nebraska, '42–'44
Lt. (j.g.) U.S. Navy Communications and Staff Officer, '44–'46
Part-time Instructor in Secondary-Educ., University of Nebraska, '46–'48
Assistant Professor of Secondary Education and Supervisor of Science, University of Nebraska, '48–'51
Appointed to Graduate Faculty, University of Nebraska, '51
Associate Professor of Secondary Education and Supervisor of Science, University of Nebraska, '51–'53
Associate Professor and Director, Bureau of Educational Research and Service, University of Kansas, '53–'55

Professor of Education and Director, Bureau of Educational Research and Service, University of Kansas, '55–'59

Chief, Science, Mathematics and Modern Foreign Language Section, U.S. Office of Education, Washington, D.C. (on leave from the University of Kansas), '59–'60

Professor of Education, University of Kansas, '60–to date

In addition he taught in the summer sessions at Wayne State College, Wayne, Nebraska, and at the University of Maine.

Professor Smith served in the U. S. Navy (1944–46) during World War II with the rank of Ensign and Lt.(j.g.). His tour of duty was in the Southwest Pacific—Okinawa, Philippines, and China. He was awarded the Philippine Liberation ribbon and the Occupation ribbon for duty in China.

Memberships in organizations include: National Association for Research in Science Teaching, National Science Teachers Association, American Association for the Advancement of Science, American Association of University Professors, National Education Association, Kansas Academy of Science, Phi Delta Kappa, and the American Education Research Association.

Honors include:

Regents Scholarship Winner—Nebraska, 1934

Brownell Scholarship in Science Education, University of Nebraska

Past-President, Omicron Chapter, Phi Delta Kappa, University of Nebraska

Past-President, Kansas Chapter, American Association of University Professors

Past-President, National Science Teachers Association, 1958–59.

Secretary, Section Q, American Association for the Advancement of Science, 1956–to date

President, National Association for Research in Science Teaching, 1961

President's Committee on Education of Scientists and Engineers

Chairman, Advisory Board, Film Project, National Science Teachers Association

Chairman, Research Planning and Review Committee, Council for Research in Education.

Many other national committees

Listed in Who's Who in Midwest, Who's Who in American Education, American Men in Science.

Fellow, American Association for the Advancement of Science.

The title of Doctor Smith's Masters Thesis completed at the University of Nebraska, 1941, is "An Evaluation of the Science Program in the Wayne High School." His doctoral dissertation completed at the Univerity of Nebraska in 1948 is entitled "A Determination of the Relative Effectiveness of Sound Motion Pictures and Equivalent Teacher Demonstration in Ninth Grade General Science." Other publications include:

1. "A Determination of the Relative Effectiveness of Sound Motion Pictures and Equivalent Teacher Demonstrations in Ninth Grade General Science," *Science Education,* 33:214–221, April 1949.
2. "The Relationship Between Intelligence and the Learning which Results from the Use of Educational Sound Motion Pictures," *Journal of Educational Research,* 43:241–49, December 1949.
3. Intelligence as a Factor in the Learning which Results from the Use of Educational Sound Motion Pictures," *Journal of Educational Research,* 46:249–61, December 1952.
4. Chapter 9, "Motion Pictures, Intelligence, and Enrichment," *Enriching the Curriculum Through Motion Pictures,* edited by Dr. Wesley C. Meierhenry, University of Nebraska Press, 1952.
5. (With Harry Bard). Serial 16, "In Service Training," *Resource, Conservation Education* (Mimeographed report).
6. "Qualitative Aspects of Gain on Final Over Initial Measures in Achievement Testing," *Audio-Visual Communication Review,* 1:167–174, Summer 1953.
7. "Some Problems in Health Education," *University of Kansas Bulletin of Education,* Vol. 8, No. 1, pp. 1–4, Lawrence, Kansas.
8. Prepared the following instructional syllabi for high school science courses of the University of Nebraska Extension Division:
   Science Vx (Biology 1)
   Science Vix (Biology 2)
   Science VIIIz (Chemistry 2)
   (Also did extensive editorial work on Science VIIz, Chemistry 1)
9. (With R. C. Cook). "A Science Room Design for the Small High School," *The American School Board Journal,* 128:59–60, January 1954.
10. (With Kenneth E. Anderson). *A Summary Report to the North Central Schools of Kansas, Criterion 3: School Staff.* Kansas Studies in Education, 1954. Vol. 4, No. 1. pp. 24.
11. (With Kenneth E. Anderson). "Inheritance as a Factor Influencing Achievement in Science and Other Academic Areas," *Science Education,* 38:406–409, December 1954.
12. (With Kenneth E. Anderson). "So Parents Complain," *The Kansas Teacher,* 62:15, April 1954.

13. (With Kenneth E. Anderson and Carl E. Ladd). *A Study of 2500 Kansas High School Graduates.* Kansas Studies in Education, 1954, Vol. 4, No. 3, pp. 45.

14. (With Kenneth E. Anderson). *A Summary Report to the North Central High Schools of Kansas on Criterion 4: Administration and Supervision.* Kansas Studies in Education, 1955, Vol. 5, No. 2, 62 pp.

15. "An Approach to the Problem of Sex Education," *The Clearing House,* 30:38–40, September 1955.

16. (With Kenneth E. Anderson, Nathan S. Washton, and George W. Haupt). "Second Annual Review of Research in Science Teaching," *Science Education,* 38:333–365, December 1954.

17. (With Kenneth E. Anderson and James K. Hitt). "The Second Annual K. U. Junior College Conference," *University of Kansas Bulletin of Education,* 1955, Vol. 9, pp. 63–73.

18. (With Kenneth E. Anderson). "Preservice and Inservice Education of Elementary and Secondary-School Teachers," *Review of Educational Research,* 24:213–226, June 1955.

19. (With Nathan Washton, Jacqueline Buck Mallinson, Clarence Boeck, and Thomas P. Fraser). "Third Annual Review of Research in Science Teaching," *Science Education,* 39:335–371, December 1955.

20. (With Kenneth E. Anderson and Oscar M. Haugh). *Thesis Handbook.* University of Kansas, Lawrence, Kansas, 1956.

21. (With Kenneth E. Anderson, Fred Montgomery, and Dorothy Anderson). "Toward A More Effective Use of Sound Motion Pictures in High School Biology," *Science Education,* 40: 43–54, February 1956.

22. "Some Resources for Teaching Science in the Elementary School," *University of Kansas Bulletin of Education,* May 1956, Vol. 10, No. 3, pp. 87–94.

23. Review: Margaret E. Bennett. "Guidance in Groups," *The Clearing House,* 30:561, May 1956.

24. (Symposium). "Symposium: Needed Research in Science Education," *Science Education,* 40:363–369, December 1956.

25. (With Kenneth E. Anderson and Einor V. Kullstedt). *A Study of 376 Kansas High School Graduates.* Mimeographed, 1956.

26. (Symposium). Report of the Committee on Instruction, American Association of University Professors. (Mimeographed report on Advisement practices, 40 pages), February 1957.

27. Review: "Compton's Pictured Encyclopedia," *The Science Teacher,* 24:197, May 1957.

28. (With Kenneth E. Anderson and Oscar M. Haugh). *Thesis Handbook.* Revision. University of Kansas, Lawrence, Kansas, 1957.

29. (With Nathan S. Washton). "Science in the Secondary Schools," *Review of Educational Research,* 27:343–356, October 1957.

30. (With Kenneth E. Anderson). "An Inquiry into some Possible Learning Differentials as a Result of the Use of Sound Motion Pictures in High School Biology," *Science Education,* 42:34–37, February 1958.

31. (With Kenneth E. Anderson and Tate C. Page). "A Study of the Variability of Exceptional High School Seniors in Science and other Academic Areas," *Science Education,* 42:42–59, February 1958.

32. "Professional Organizations and the Science Teacher," *Missouri Science News,* Vol. 1, August 1958.

33. "The Educational Film in the Teaching of Science," *The Science Teacher,* 25:282–283, September 1958.

34. (With Kenneth E. Anderson). *Topics in Statistics for Students in Education.* The Interstate Printers and Publishers, Inc., Danville, Illinois, 1959.

35. Book Review. "Counseling for Personal Adjustment in Schools and Colleges," *The Clearing House,* 33:182, November 1958.

36. "Survey of Recent Research in Secondary School Science Education," *School Science and Mathematics,* 58:613–619, November 1958.

37. Book Review. "Values in Culture and Classroom," *The Clearing House,* 33:248–9, December 1958.

38. "Studying Science Successfully," *Compton's Pictured Encyclopedia,* 1958.

39. (With Lawrence E. Penny). "A Practical Means of Determining Pupil Socio-Economic Status," *Peabody Journal of Education,* 36:204–213, January 1959.

40. *Action for Science Under NDEA.* NSTA, February 1959. I actually wrote this document but because of my subsequent appointment as Chief, Science, Mathematics and Modern Foreign Languages Section in the U. S. Office of Education (but prior to publication of the document) it was not expedient to have me listed as the author. Thus, I am actually listed among the consultants to the NSTA Committee on Facilities.

41. "The Teacher's Stake in the National Defense Education Act of 1958," *Science World.* 5:1–4, April 7, 1959.

42. "Improving the Quality of Science Instruction in Elementary and Secondary Schools," *The American Journal of Physics,* 27:259–263, April 1959.

43. Editorial, *The Science Teacher,* 26:212, May 1959.

44. (With Lawrence L. Penny). "Educational Opportunity As a Function of Socio-Economic Status," *School and Society,* 87:342–43, September 12, 1959.

45. "Report on Title III National Defense Education Act of 1958," *The Science Teacher,* 26: 534–538, December 1959.

46. (With Kenneth E. Anderson). "Science," *Encyclopedia of Educational Research,* pp. 1216–1232, edited by Chester W. Harris, Macmillan Company, 1960.

47. "The NDEA or New Devices Electrifies Atom," *Elementary School Science Bulletin,* Issue No. 51, January 1960.

48. "Some Implications for the Training of the Junior High School Science Teacher," *Science Education,* 44:37–39. February 1960.
49. "National Defense Education Act: Title III," *NEA Journal,* 49:63. March 1960.

Professor Smith's philosophy of education has been adequately reflected in a University of Kansas Committee on Undergraduate Education report. Professor Smith served as Chairman of this committee. Professor Smith comments or quotes from this report as follows:

We established our projected program on teacher competencies to be developed in four categories. These were the teacher: (1) as a broadly educated and cultured individual; (2) as a physically, socially, and emotionally effective person; (3) as an adequately specialized person in his teaching field or fields and (4) as a professionally competent person.

In considering category 1 above, we identified 5 aspects of competence which the broadly educated and cultured individual should have developed. These related to (1) man and his language, (2) man and his society, (3) man and his culture, (4) man and himself, and (5) man and his physical world. For illustrative purposes I will quote the detailed elaboration on point 5. Although this was a committee report, the words in this section were essentially mine.

Man and His Physical World (His Understanding of the Physical Environment).

Man can neither understand the present or predict the future without a grasp of the role of technology and science in the modern world. Without a sound grounding in basic sciences, no man can be educated, he cannot understand the major problems of mankind. Thus, his education should acquaint him with the tremendous impact of science, and especially technology, on social institutions and on the culture generally.

A university graduate should have a knowledge of those portions of the biological and physical sciences and of mathematics that are basic to an understanding of the world about him. He should be able to bring this knowledge to bear on his personal problems and to appreciate the role of scientific information and methodology in reaching solutions for the problems of society.

Professor Smith is very much "concerned that science be recognized as an essential in the education of all and not merely for those whose vocational orientation is in this direction. Too many seem to have forgotten the role of science as an essential general education ingredient these days."

Professor Smith's greatest contributions to education, and especially science education, have been through his work with NDEA, at the University of Kansas, his work on committees and as President of the National Science Teachers Association, as Secretary of Section Q of the American Association for the Advancement of Science, as Chairman of the Research Planning and Review Committee of the Council for Research in Education, and his activities in the affairs of the National Association for Research in Science Teaching. In commenting on his work with NDEA, Professor Smith says:

Perhaps my greatest contribution (?) was in any influence I might have had in the early days of NDEA in doing all in my power to stress the necessity for the appointment of qualified personnel to positions as state science supervisors. Plan after plan from the States was criticized because the standards established for such personnel were too low. In general, I feel that the appointments eventually made by the States were good appointments—in the main, extremely bright and capable young men. How much my influence had anything to do with it is, however, a matter of conjecture.

Furthermore, I feel that my section and I were extremely effective in building bridges of good will between the States and the U. S. Office of Education at a time when there were many suspicions and uncertainties about NDEA and its administration. I also feel that the section under my direction was extremely helpful to young state supervisors in terms of publications, conferences, direct correspondence, and visitation.

In another sense, I hope I have made some contributions at the University of Kansas. At the time I came here the science education program was certainly minimal. Today we have improved facilities, five or six times as many undergraduate majors and an extremely rapidly expanding graduate program in science education. (We had virtually no graduate program in science education when I came here.).

Professor Smith describes his current interests as being in research on equipment and materials purchased under Title III NDEA, problems in administration and supervision related to science instruction, the use of audio-visual aids to instruction, and socio-economic factors and their relation to educational achievement.

Doctor Smith has the honor of serving as president of two distinguished science

teacher organizations, first as president of the National Science Teachers Association and now as president of the National Association for Research in Science Teaching. (Professor J. Darrell Barnard reversed this order, first serving as President of NARST and currently as President of NSTA).

Many and noted have been the contributions made by Professor Smith to the cause and progress of science education. When the final evaluation of leaders in science education in the last half of the Twentieth Century is made, the name of Herbert Andrew Smith could well be included high up in the list of the first ten. To a distinguished leader in the science teaching field goes the Twenty-Eighth Science Education Recognition Award.

CLARENCE M. PRUITT

THE HERO IMAGE IN EDUCATION *

FLETCHER G. WATSON
Harvard University, Cambridge, Massachusetts

EVERY culture and subculture has its hero images. The Iliad and the Odyssey describe the heroes of the Greeks. The Eddas report the sagas of the Norse heroes. Most of the world's great religious groups have an individual, rather than just a set of ideas and precepts, as the image of what the good life should be.

Each subculture also has its heroes. We are all familiar with those of the sporting world, of the theater, of literature and the arts. Likewise, each country has its heroes. We have just recognized Washington and Lincoln as great men whose pattern of life and intentions are worthy of emulation. The pilgrims, the Kentucky frontiersmen, the heroes of the prairies, the tycoon who rose from rags to riches, like Horatio Alger, and the man in the grey flannel suit are among the hero images admired in this country. But where are the educational heroes?

If you ask a neighbor to name one or more outstanding educators, you may hear mention of Horace Mann and perhaps John Dewey. Possibly some few might mention James B. Conant, but his image is remote, more of an adviser and conscience than one whose behavior should be copied. Even those who wish to attack organized education have a difficult time to find specific targets. Because we have no current hero-figures, poor John Dewey, who is misinterpreted, dead and gone, and defenseless, and the phantom "progressive educator" are the major targets for attack.

Hero images are important to every culture. They are symbols of the adult value system that should be emulated by the young. Often the image is far grander than the individual actually was, but that is not important because the hero is given all the traits that the adults admire. He becomes a symbol of perfection to be admired and copied by the young.

The difference between the image and reality was clearly demonstrated last year when Ted Williams, an outstanding sport hero to many youngsters, spat at someone. Now I do not mind greatly if some baseball player occasionally loses his sense of good taste; but heroes should not be subject to human frailty. The uproar was about the desecration of the *image* of Ted Williams. In your youth probably many of you were encouraged at some time to "be a good boy and you might grow up to be president of the country." Now that radio and television make real the actual human characteristics of the president, and we

* Presented at the Thirty-Fourth Annual Luncheon, National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 25, 1961.

are aware of the crushing responsibility that goes with that office, we are less likely to hold the image of the president before our children. However, the president has always been a national hero.

If the hero image, a personification of all the proper virtues, were not such an impressive and useful device, we would not find that practically every culture that has existed has had its heroes. Often the anthropologist and the sociologist can determine much about the values and the nature of a culture by a study of its hero images.

Now, why do we not have heroes in education? Somehow the idea is current that all educators and teachers are equal in competence. Therefore, none of them should be honored as exemplars, for this necessitates making choices among equals. Since some worthy persons may not be honored, none should be. Or, when everyone is honored, none are distinguished. As a result we have no figures which we hold before the youth—saying, if you wish to succeed in education, be like these heroes.

The contrasts between education and all other fields of activity are sharp. There is the Hall of Fame for public servants. Among scientists there are Nobel prizes, numerous awards to chemists announced at each of their meetings, and awards to outstanding teachers of physics. The medical and legal professions have their honors and distinctions. And certainly business is not lacking in status symbols. In the arts we have Oscars and Emmies, as well as Pulitzer prizes, and international awards.

In every case, those to receive the awards are chosen by a committee of their peers. Often the decisions are difficult to make, but rarely is there contention that the recipient of the award is unworthy. But notice the obligation put upon the selection committee, it must have some distinct criteria of excellence. So now, perhaps, we see one reason for the lack of distinctions in education—we do not have, or are not willing to state, criteria of excellence. But if we do not know what constitutes good work among our peers, who else can? So to outsiders, educators appear as a spineless amorphous group lacking a clear image of its heroes. When one fourth of the nation is enrolled in school, and educational budgets are second only to defense budgets in their demands on the public purse, this is a sad state of affairs. We have no acknowledged spokesman and no heroes to hold as symbols of accomplishment before the beginners.

The mischief that results from this lack of heroes appears in many forms. First, we have no acknowledged spokesman for education. The United States Commissioner of Education occupies a political position—which often is suspect. To be candid, we have only on rare occasions had a Commissioner who had the courage of his convictions and spoke out loud and clear. The numerous state commissions have local allegiences, and none can speak for all. Professors rarely have the opportunity to command much public attention, irrespective of what they say, unless it is derogatory. So we have no spokesman to speak boldly and clearly about a most important aspect of public concern.

But "nature abhors a vacuum," so numerous self-styled prophets, with happy ignorance and narrow frames of reference, command the public attention and hawk their personal prejudices unopposed. The science educators of the country have been the special victims of their own lethargy. By seeming to lack in self-esteem and acknowledged leaders, we have been displaced by self-confident professors of the sciences who are quite certain they can remedy the major curricular problems of our schools. Being brilliant individuals of recognized accomplishments in science, they have been able to gain access to those controlling the purses of public and foundation funds. So, with financial support of a magnitude never before known in education, they and their colleagues have moved in to clean our house. While none of us

would contend that much did not need to be done, some of the most influential ones seem to lack any comprehension of the basic purpose of schools in this country. Rather, they have designed instructional programs for the rare pupils of abilities like their own with the intent of providing in the secondary school the equivalent of the introductory year of collegiate science in their speciality. Few seem to be concerned for the mass of non-scientifically minded pupils who go to college, or to the even greater number of pupils who terminate their schooling in the secondary school. We still have deep obligations to the many pupils of modest abilities, but the programs devised thus far, excellent as they may be for a few, are unrealistic for most pupils.

While we talk of teaching and education as a profession, this frequently is "whistling in the dark" to keep our spirits up. We often fail to act like a profession. We do not identify and honor our leaders and thereby make clear for all to see whom we consider our heroes. Neither do we establish and maintain standards of admission to various groups. I worry greatly about some of the people admitted to doctorate programs who will become, in the public eye, colleagues of you and me. Also, I am not impressed by the quality of the research done in science education, for which this group is primarily responsible both for its instigation and design, and for its publication. We are not critical in a constructive manner; whatever is done seems to be blandly accepted, and just as blandly forgotten.

I, therefore, am especially hopeful that we may be able to establish an annual award for excellence in published research in science education. Already a committee from NARST and AETS is attempting to locate a source of funds. Ultimately a selection committee of our most competent members must be chosen to serve as judges. And just as clearly, a number of us, by virtue of our involvement, must be ineligible for consideration. This is at least one small way among many in which this organization can establish a standard of excellence and create our own public hero image.

CHALLENGES TO THE IMPROVEMENT OF SCIENCE EDUCATION RESEARCH * †

William W. Cooley

Harvard University, Cambridge, Massachusetts

This panel [1] has been assigned the task of considering the potential of the research resource center. Our common concern is the improvement of research in science education—the question is, how might research resource centers help? To give my answer to this question, I should like, first of all, to point out a few major difficulties with today's research efforts, then try to define good research, suggest possible ways of producing good research, and finally, examine alternative proposals for improving research in science education.

It would be easy enough to point out *technical* difficulties with present research, including poor research design, improper statistical procedures, untenable assumptions, ungeneralizability of hypotheses tested, etc. However, such technical short-

* Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 23, 1961.

† The author wishes to acknowledge the profitable discussions of this topic which were held with faculty and doctoral candidates in science education at the Harvard Graduate School of Education.

[1] Panel on "The Potential of the Research Resource Center."

comings are merely the result of more fundamental difficulties. One of our basic problems is that we rely almost exclusively upon degree candidates for the conduct of research.[2] Such research is necessarily hurried and harried, since the candidates do not have the time either to design long-term research projects or to develop the technical competencies needed to arrive at convincing, replicable results.

Another basic difficulty is that we often attempt to attack our issues or problems head on without sufficient attention to the framework underlying them. We ask specific questions such as whether or not the laboratory experience should precede, accompany or follow class discussions (as in Chapter III, page 18, of the NARST *Issues* summary), rather than ask questions about how children learn science concepts. Our behavior is somewhat like that of the alchemists who wanted to turn lead into gold. All their time and energy was expended on repeated empirical head-on collisions. Today, by making use of the knowledge about the nature of matter, the alchemists' dream is quite feasible. Similarly our own advances in science education will come *not* from a direct attack upon the obvious issues and problems, but by slowly teasing out more basic relationships which will become useful, general, operating principles.

A third basic difficulty is that there is not now a definite structure of criticism in our "discipline." If research is conducted in an area where naive and inconclusive work is published along with the good, and if poor work goes uncriticized, improvement in the conduct of research can hardly be expected. The natural sciences which we teach give us reliable and accurate accounts of the world, in large part because of the system of checks and criticism which these disciplines have evolved, yet we fail to recognize this in our own research field.

This lack of structure of criticism in science education research is illustrated by our journals in which there are no sections of "letters" in which specific reports are criticized for specific shortcomings. We all tend to deplore the general body of research, but no one is saying what is wrong with what research, so that we could slowly work toward research that inspires confidence. Also, at our meetings, we tend to march through a full schedule of research papers with little or no time for discussion so that *everyone* might be able to present his study. The frequent summaries of research and the "implications" papers of our organization (which made up about 20 per cent of *Science Education* Vol. 44) would seem to be one avenue for research evaluation, but here only general statements are found, and criticism of specific efforts is only through omission. If a paper that is below any acceptable standards of research gets into our literature or is placed on our programs, the investigator must be told where he fell short. Otherwise, incompetent research will continue to mask the valuable research which our discipline should be building upon.

We could no doubt point to other major difficulties, but if you agree that the three mentioned above are legitimate complaints, that is all I need as background for the points which follow.

Before we turn to possible solutions for these difficulties, perhaps I'd better pause and try to give you my conception of *good* research. This seems a reasonable preliminary to the question, "What is needed to *produce* good research?"

In the recent NSSE Yearbook, Fletcher Watson and I attempted to delineate areas which we felt contained worthy and researchable questions. Implicit in that chapter ("Needed Research in Science Edu-

[2] For example, of the 420 pages in Vol. 44 (1960) of *Science Education*, only 70 pages (17%) consist of research reports by NARST members, and half of those were reports of previous doctoral dissertations. Therefore, less than 10 per cent of the latest volume of the official journal of this *research* organization consists of post-doctoral research by its members.

cation")[3] is our conception of good research. First of all, it utilizes knowledge from the frontiers of related disciplines. Too many of the previously reported studies appear to be designed and conducted as though psychology, psychometrics, and other behavioral sciences do not exist (nor is much attention given to philosophy, in questions concerning the aims of science education). One characteristic of good research, then, is that it builds upon the established principles and research techniques of related disciplines, whenever relevant.

However, the use of principles and techniques developed in related disciplines, though necessary, is not a sufficient condition for good research. In a current five-year study of the process of becoming a scientist, we are using the psychologist's developments in personality assessment, procedures in multivariate analysis developed by statisticians within the last ten years, sociology's techniques for measuring socio-economic status of the family and parental expectations for the son, and the engineer's most recent high speed, stored program, digital computer. But all of this will amount to very little if we should fail to build upon, derive specific hypotheses from, confirm or modify a theoretical structure of the career-choice process. This is *not* to insist that all educational research must test hypotheses from the theories of related behavioral sciences. The essential point is that our research efforts should be directed toward a more fundamental understanding of the basic processes which occur within the domain of science education. We cannot continue to go poking around at "issues" and expect that we shall develop a body of knowledge which will be *generally* useful in confidently modifying educational practice.

Having delineated a few of the characteristics of good research, we can now ask what *is* most needed to produce research which seeks to understand the basic processes involved in teaching and learning science, research which will serve as a basis for the work of developing and improving specific methods and materials, research which takes advantage of developments in related disciplines? The answer is simple. Good people!

In discussing the scientific enterprise we too often forget that research is done by people. The most elaborate organization ever conceived will not produce good research without good people *doing* research. What we might be able to do collectively, however, is develop a program which will encourage competent people to focus their attention upon the basic processes involved in science education.

One approach might be to offer research grants to behavioral scientists for examining aspects of science education. However, even if more behavioral scientists could be encouraged to use our domain as testing grounds for their hypotheses, the extent to which their efforts would modify our practice would be questionable. Those men are usually more interested in contributing to their own disciplines, and publishing in their own literature, and this limits their usefulness to us in our existing structure. (We've already observed that little use is made of the developments of other disciplines. At least our published research does not reflect familiarity with their literature.) This finally brings me to my central point.

We need to develop a core of men who will serve as the "missing link" between the frontiers of the study of human behavior and our own specific concerns. There are about twelve universities today which are preparing most of the doctorates in science education. I believe that these programs tend to be staffed with men whose primary interests and responsibilities are in the realms of action and service (direction of teacher training; conduct of in-service institutes and summer workshops;

[3] F. G. Watson and W. W. Cooley, "Needed Research in Science Education," *Rethinking Science Education*, 59th yearbook of NSSE, 1960, Chapter XVI.

writing textbooks, and preparing other new curriculum materials). Certainly worthy enterprises. But the missing men are the faculty members devoting primary attention to research. We cannot expect the research in our field to improve without such men. As the recent President's Science Advisory Committee Report[4] on basic research and graduate education pointed out, competent graduate research is done in an atmosphere of active faculty research. Research is not something someone sandwiches in between a multitude of other activities. It is a fulltime job; and we cannot expect to get the competent research we sorely need until such men are on the staffs of every graduate program in science education.

Some of you are no doubt thinking that such men are neither possible to obtain nor necessary to have—impossible because of the lack of money for extra staff, and unnecessary because there are behavioral scientists on your university faculty to whom your candidates can turn for special help as problems arise in their dissertations.

One way of solving the financial problem is to support research positions (at least in part) through grants from such organizations as the Cooperative Research Branch of the U. S. Office of Education. The commitment to a research grant would also be partial insurance that the man's time would not slowly be eaten away by the demands of the school's service functions. The research grant would not be a permanent financial solution, but it could help to get things started. Certainly some teaching, such as a graduate research seminar, would be desirable and would help to support a research position.

The question as to the *necessity* of having a research position on a science education staff is not easily answered. If there is general agreement that our research efforts should not continue to rely almost entirely on the work of students, and if most graduate school faculty members are already overly committed with the school's necessary and important action-service functions, then the need for additional staff seems to follow. What may not seem necessary is my plea for the performance of basic, behavioral science investigations. There are two main reasons why I believe basic research to be necessary. First, we cannot expect to utilize the frontiers of knowledge in the applicable sciences if none of us is familiar with those frontiers. The best way of knowing the frontier is to work there. The emphasis is on frontiers because the scientific advances in any field involve a process of successive approximations, so that the most recently developed principles of human behavior are generally the most reliable.

The second reason is that much needs to be done in terms of adaptation and development before the fruits of psychology and sociology become useful in the educational setting. We *must* be concerned with the sciences of human behavior because it is human behavior we are dealing with in the schools. A part of this basic research task is ours. Although the study of pigeons pecking for food or of rumors during war may yield basic psychological or sociological principles, the task of selecting, testing, and refining such principles into educational operations involves a type of basic research not now common in our field. I call it "basic" because the focus is upon building a science of human behavior in the educational setting. It is *not* a disorganized empirical attack (in the manner of the alchemists) upon the obvious and immediate concerns of educators.

My remarks thus far seem to have taken me rather far afield of today's topic. How do research resource centers fit into the scheme I've presented? The centers were conceived in an effort to improve the type of research currently being done. Although Master degree projects may be

[4] "Scientific Progress and the Federal Government," *Science*, 132:1802–1815, (Dec. 16, 1960).

improved as a result of these efforts, educational theory and practice probably will not. Furthermore, the current plans involve setting up centers around issues, and this focus would serve to entrench the head-on empirical attack on the obvious problems even more firmly in our research methodology.

Another major shortcoming of the proposed center concept is the emphasis on *resource* rather than research. I am wholeheartedly for research centers, but differently conceived. Each research center should evolve specific areas (not be assigned or assign itself issues) in which research is *undertaken*. This evolution will necessarily reflect interests and strengths of each local faculty. I say "evolve" because research is *not* a process during which someone identifies a problem, defines it, compiles a relevant bibliography, performs an experiment, and thus solves the problem. It sometimes appears as though we have come to believe the all too frequent general science textbook definition of "the scientific method."

Although it is easy to be negativistic toward sincere and thoughtful proposals, it is quite difficult to develop better ones. We seem to have a common concern and desire: to improve research in science education. Research resource centers will no doubt be useful, but I would prefer not to see us place too much faith in them as a panacea. There is just so much time and energy available, and we must decide what approaches are most likely to yield the greatest improvements. The following four suggestions might be considered along with the proposal for research resource centers.

1. We should identify the more definite, organized *research* operations at universities preparing doctorates in education. Our research coordinator could compile and make available a summary of these activities. Only centers having a *going* program of research should be listed. Such listings could be published in *Science Education* and would be useful for stimulating the establishment of more definite programs at other institutions. The listings would also make it possible for prospective graduate students to identify institutions at which they might study particular aspects of science education with profit. It is not too clear today who is doing what. This suggestion is not an attempt to establish a "research elite," but rather to provide a means for recognizing those areas which are currently being researched on an organized basis, so that the practitioner can know where to seek competent advice and emerging centers can decide where to place their own emphases.

2. We should improve our official journal through the establishment of an editorial board which would pass for publication only competent research. I suggest a board because the improved screening of papers is too much to ask of any single man. If more careful editing results in too few papers, invitations should go out to behavorial scientists who are conducting research which is related to science education. This would bring their work into our literature and would tend to assist us in setting standards for research.

3. The official organ of this association should contain a section devoted to constructive criticism. A "Letters" section suffices in the journals of many other disciplines. If such criticism is not received on a voluntary basis, it should be actively sought—not simply for the sake of criticism, but because we have generally agreed that too much of our current research is poor. The "incompetent, irrelevant, and immaterial" aspects of existing studies must be clearly pointed out. We won't get anywhere until we begin to get more specific in our critiques. This is an integral part of any scientific enterprise.

4. The association, together with the U. S. Office of Education, might wish to sponsor special summer conferences at which the men now actively engaged in research meet to discuss specific research problems and share their competencies with others who wish to become more active in research. We don't seem to have much difficulty setting up big conferences for general discussions or workshops to write new textbooks. Perhaps a six-week session on concept formation would be a good place to start.

There are no doubt many other things NARST might do to stimulate and improve research in science education We must remember, however, that any action must be related to *people doing research* and not peripheral activities which are only substitutes. Much needs to be done for the improvement of science education which requires leadership and action. Even more needs to be done in basic research. NARST is the only organization devoted to research in science education and only its membership can provide the stimulus needed through the conduct of competent research. This is the challenge we face.

THE PURPOSES, OPERATION AND SERVICES OF A RESEARCH RESOURCE CENTER: AN OPERATIONAL APPROACH *

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Foreword: As the National Association for Research in Science Teaching seeks both to widen and deepen its research endeavors, two approaches are manifest.

First, the design of fruitful educational research requires imaginative vision which must operate within the precise framework of a statistical level of confidence. Only if this is achieved can the results of research be accepted. Yet "can" is not "will." The results of a study must say to teacher or administrator either, "I can prove it wrong in my case," or "I have always though that this was so, for I have seen it happen that way often." A study must then unequivocally resolve a real conflict, or must give assurance to hundreds that they have not been alone in their search for answers to pressing daily problems in education.

Second, the initiators of research studies have also been alone. They have hopefully probed for places in the science education structure which might be sensitive to experimental attack. Isolated areas have indeed been found. Suggestions that profitable changes in the curriculum could be made have been discovered. But neither manpower nor money has been available to obtain definitive or normative rubrics for change until recently. The changes now being made have not generally been initiated by individuals, nor have they been based on previous research. Rather, they have used the massive approach. Deductively formulated theories of education are agreed upon by a team, and wide trials are made to see if a measurable difference is made in performance in the classroom. The high energy level and the interest engendered by any experiment have undoubtedly helped in the acceptance of such new studies. The materials used are superb; whether they will serve for years as guides and prototypes for science education in a changing world has not been considered, and indeed it is unfair to expect them to so serve.

If research into the basic ways of learning, and the complex drives, anxieties, and hopes of young people and children are to be considered as factors of those ways, then a diffuse but concerted effort to learn the ways of youth must be undertaken. NARST is ideally suited to do this. Its members touch on every corner of the country, indeed of the world. They have learned to be patient and careful. That no single piece of research in science edution research has rocked the educational world is not for want of desiring and striving. Is this the result of the lack of manpower, money—and communication? On the following pages there is suggested an operational approach to the problem of communications among the Research Resource Centers now building.

Part A. Possible conceptual schemes for the operation and services of a Research Resource Center.

1. *Present planning.* No change in current procedure; reports to members are made at the beginning and at the completion of studies.

2. *Probe planning.* Each institution reports *before* any study is finally approved, to see if slight modifications would help to obtain a better fit with some larger scheme elsewhere.

* Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 23, 1961.

3. *Pool planning.* Set up a pool of small correlated studies in each Center or in individual member institutions, with a specific design to be followed. This would be helpful to persons working on papers, who want to do classroom research in their own schools, or who seek knowledge about learning processes so as to write texts or tests or syllabi. This needs planning-before-publication in such pools, and it requires constant communication with those working with the studies in each pool. Reports of difficulties and successes should be made even before studies are ready for publication.

4. *Prepared planning.* This is a large-scale, foundation-sponsored endeavor. Three to five years' existence should be assured. Longitudinal studies would show an important gain over most present studies as they could then involve large numbers of pupils. The design suggested in the NEA Research Bulletin for December 1960,[1] there used for opinion studies, might be modified for other types. More sophisticated statistical techniques are indicated, utilizing intraclass correlation, analysis of variance, and for studies involving socio-economic factors, multivariate analysis. Chapter XVI of the Fifty-ninth Yearbook[2] suggests other procedures. A competent educational statistical designer should be involved from the beginning, and an electronic computer will be needed all during the study, not just at the end.

5. *Goal and task.* The most important task will be obtaining the assurance of acceptance of all the participants, from professor to pupil, of any experimental study. This assurance can be obtained only through the process of arbitration and mediation before the initiation of a study.

Pragmatic legal realism is the tool for change in science education. New norms must be set up. Changes sought in science education are achieved through the application of deductively formulated theory, in this case a theory of learning. Some theories of learning are consistent with a cultural theory of values which is acceptable to the schools of the democracy which both "is" and "ought to be." One or more of these theories will always be implicitly involved in any science education study.

Part B. Communications media for efficient use of the Centers.

1. *Present.* Improved nation-wide reporting, hopefully annually in September-October, for research completed in June. Appropriate educational periodicals would always reserve space for research reporting in every issue. If this space priority were not utilized, last minute fill-ins from existing manuscripts would always be possible.

2. *Probe.* Capsule reporting on identicals forms supplied by NARST or the U. S. Office of Education, would *give information* about plans and would *request responses.* This exchange would be stimulating, would alert other contributors so that they could avoid exact duplication unless replication was planned for. This plan might create national voluntary cooperation in large scale research. It has a good chance of success if the list of probes were to be made available directly to graduate students, even though these people would normally not be required to do research.

A much better equivalent plan would be to have these capsule reports microfilmed and advertised by University Microfilms at the University of Michigan at Ann Arbor. Costs are modest, five cents for each typewritten page. NARST could guarantee a minimum distribution among its members, and students would pay for their own choice of topics.

[1] Research Division of the National Education Association, *Research Bulletin*, Vol. 38, No. 4, December, 1960, National Education Association, 1201 Sixteenth Street, N.W., Washington 6, D. C.

[2] Fifty-ninth Yearbook of the National Society for the Study of Education, "Rethinking Science Education," University of Chicago Press, Chicago, Illinois, 1960.

3. *Pool.* The pool of studies would almost certainly have to be on microfilm, as it would run to hundreds of individual items annually. Direct mail communication between students or classroom teachers engaged in similar studies would by-pass the staff of the Centers and so reduce the volume of correspondence. Each item of correspondence, however, would be filed as a carbon at the center originating the items in any one pool. Prepublication reports on microfilm would be widely and swiftly disseminated.

4. *Prepared.* The prepared-planned research would have its own publications. A newsletter, a *Journal* of Science Education Research, and a library of past and current studies in science education would be staffed permanently. Over the years, older studies from the Journal of Educational Psychology, the Journal of Experimental Education, the American Journal of Physics, and the Psychological Review would be excerpted and evaluated in the Journal of S.E.R. The subject-matter journals in general science, chemistry, and biology are more readily available, but some material from these would be included.

Note that this Journal would go to every institution of teacher education in the United States and to selected overseas institutions. These communications media would be part of the contribution of the sponsoring fund for the life of the grant.

5. *Communications personnel.* It is evident that a specialist in science-education writing will be needed to head the staff of the publications. It is likely that this person will also need to have done considerable technical writing in at least two science disciplines. He should have status in both of these areas. He will be active in national and international journalistic and scientific societies.

A modest staff will include trainees in the art of science education communications. The publications, therefore, should be physically centered at a university where there exists a doctoral-level program in science writing. This in turn might fix the executive offices of the prepared-planning group.

Part C. Manpower and expense levels.

1. *Present.* Resources "at home" could be reorganized in some cases if a national communications plan were to be effected. Groups of students in regular classes would be dignified by their contact with similar groups in other institutions. Seminars formed for the express purpose of doing simple research would also feel a kinship with the national effort. NARST would become more nearly a symbol of science education research for *every* science education student.

Individual professors, carrying on their own research, would likewise benefit from the group solidarity of NARST.

Doctoral candidates often have strong commitments to work on problems they long have been troubled about. They could find more personal contacts with like-minded researchers. An annual listing of candidates seeking problems and asking opinions of other candidates as to the worth and feasibility of a problem could be circulated months before present publications arrive.

Doctorate committees which must approve dissertation problems would have the opinions of science education specialists from many institutions as to the problems' scope and value.

2. *Probe.* The addition at each institution of a quasi-permanent REPORTER who would handle all communications would seem to be a minimum commitment for successful operation of this plan.

3. *Pool.* Extensive staff planning in each Center would be necessary. The REPORTER would be a full-time person. Clear and accurate descriptions of planning procedures and accurate descriptions of studies will require national agreement on a *technical vocabulary of science education* which will, of course, be derived

from existing sources plus some specialized terms. The word "understanding" does not appear, for instance, in some standard educational dictionaries.

Also, an agreement on the criteria for a research study must be arrived at. There have been several committees over the years seeking to do this, and at least two publications listing the criteria are available.

The REPORTER would prepare copy for fall publication, during the summer, and send it to appropriate current periodicals or to the *Journal of S.E.R.*

4. *Prepared.* A full-time staff, consisting at least of an Editor and secretarial help, will be necessary. The Editor will need to maintain constant communication with the Centers to ensure feed-back on purposes and plans.

The Director of the prepared-planned, foundation - sponsored, three - to - five - year study would be in residence at the site of the *Journal of S.E.R.* His staff would be drawn from able educators and scientists from *all over the world,* who would ordinarily be in residence for shorter terms than the life of the study.

OBJECTIVES

All of these plans have something in common. They require some to much financial help. They will all take thoughtful preparation and constant critical evaluation. The mediation - arbitration technique, rather than the majority-decision device, seems to be a better base for long-continued existence of a plan.

The need for a measure of the validity of the concepts of education that science education now believes it is working with will make many readers ask from whence this is to come. Perhaps the *first task* facing NARST is to sit down with philosophers who would extend our thinking beyond what will be done next year—which this paper has, perforce, had to consider for the most part.

SURVEYS AND STATUS STUDIES *

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IN approaching the definition and classification of the types of studies that may be carried out in science education research, perhaps we should remind ourselves that there has been a long history of controversy and much disagreement among scholars and research workers concerning such classification. So if there appears to be some overlapping or even disagreement among the members of this panel, with regard to research in science education, it need not be at all surprising or particularly alarming.

A hasty survey of the literature made in preparation for this panel contribution, revealed that practically every attempt to classify research studies in education has included a type indentifiable as the one about which I am to make a brief presentation, namely, the "survey and status study." In most of the classifications observed, the survey and status study was referred to as a normative-survey,—that is a study type in which the purpose was to establish a norm, or baseline from which trends could be discerned or which might be used as a basis for judging some aspect or quality in relation to a sample or a universe. Good, Barr and Scates [1] in their *Meth-*

* Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 24, 1961.

[1] Carter V. Good, A. S. Barr and Douglas E. Scates, *Methodology of Educational Research.* D. Appleton Century Company, New York.

odology of Educational Research say: The normative survey or status study is concerned with "ascertaining the conditions which prevail in a group of cases chosen for study, and is essentially a method of quantitative description of the general characteristics of the group."

From a slightly different angle the survey or status study may be regarded as addressing itself to science educational "history in the making" in an attempt to get recordings and to make impressions of significant elements as they are developing rather than viewing them in retrospect and historical perspective. This type of research is then directed toward ascertaining prevailing conditions. It seeks answers in terms of real facts about elements of the science education enterprise about which there is some concern at the National, State, or Local levels.

NORMATIVE SURVEY AND TRENDS

While this type of research endeavor may focus attention on currently existing conditions, it should not be inferred that it is limited to the present. A status study perhaps makes its maximum contribution first in establishing baselines or bench marks for a variety of elements significant to the science education enterprise and then is repeated at intervals to probe again the same universe to find out what changes may have taken place.

The first national status study in science education was carried out by Johnson [2] in 1948–1949. This was followed in 1952 by Martin's [3] study of the status of high school biology. Currently at the U. S. Office of Education we are in the process of writing up data obtained from a status study of secondary school science teaching. This will be issued as three bulletins one of which is in print. A status study of elementary science is also in process; one on science teaching in the junior high school is in the final stages of questionnaire development; and one devoted to the supervision of science teaching is just being started. In the near future we hope to extend this series of status studies to the field of teacher education and then to keep the status data current by repeating each of the studies at five year intervals.

The results of a status or survey study should whenever possible be interpreted in the light of similar findings from earlier studies. This provides a valid base for discerning trends and perhaps for making tentative judgment about directions in which change may be anticipated over a time ahead. Thus such a study might reveal unique trends or practices in a certain segment of a sample which were much above the average and which might represent advanced and creative thinking or planning. The personnel working with such status studies should always be probing for evidence of this kind as well as for relationships which may be obscured or not immediately obvious. It is not infrequent that desirable trends may make their initial appearance as an obscure observation from such data.

WHERE SHOULD NORMATIVE RESEARCH STUDIES BE DONE?

It may seem somewhat presumptious to address this brief paper to a consideration of this topic. However, when one considers the vastness of the unresolved issues in science education it would seem that in general the study of the status of the elements is of somewhat secondary importance to many of the issues which seem more vital. It is dangerous to make such a generalization for I am sure that it is true that many of these seemingly vital issues contain factors which can be resolved only by a status survey.

[2] Phillip G. Johnson, "The Teaching of Science in Public High Schools," *Office of Education, Bulletin* 1950, No. 9.

[3] W. Edgar Martin, "The Teaching of General Biology in the Public High Schools of the United States," *Office of Education*, Bulletin 1950, No. 9.

Perhaps what I am trying to get at is that wherever possible the status and survey type of study should be the main business of bureaus of educational research in city school systems, in state departments of education, in teachers' organizations, the Federal Office of Education, and other field agencies. If we can get our status and survey data in good order through studies in process and planned as outlined above and through modifications or suggestions which can come from the field, together with comparable studies from other agencies, then our research resource centers might conceivably be freed of the necessity for this type of study, to direct their activities to other issues. Indeed, it is quite possible that in the future the U. S. Office of Education together with help from the State Departments of Education may be able to serve as a center for status and survey data. It is hoped that sometime in the future such centers as those in science education might request that certain specific data of a survey nature be obtained from the field.

SOME LIMITATIONS OF NORMATIVE SURVEY RESEARCH STUDIES

The normative-survey method of research is not especially a forward-looking procedure despite the fact that findings from this research format may be used as a basis for predictions and trends. Neither is the status survey well suited to the testing of principles or hypotheses under rigorously controlled laboratory conditions. Although one does not expect normative surveys to yield evidence for fundamental laws in a really pure form, they may enable opportunities for broad field checks upon basic principles that have emerged from experimental situations more amenable to rigid control. Thus it would seem in general that in using the survey type of research one does not seek to penetrate deeply into relationships but rather to reveal existing facts together with any suggestions of relationships within the date which may be outstanding as cause and effect.

In summary it should be noted that the normative survey or status type of study has a significant and important place in science education research. The kind of information obtainable can yield a most important service to the field. Anything that has been said either in favor of or against the normative survey method should not be construed to mean that it is either superior or inferior to other patterns. It has its place and should be used for the types of data which it can best yield. To quote once more from a previously used source.[4] "It is true that scientists do not generally regard it (the normative survey method) as a very high order of research, but that is of little consequence. Research is not necessarily carried on as an intellectual passtime of scientists; it frequently has important practical questions to answer and it must be appraised in the light of its effectiveness in answering these questions. There is no 'best' type of research in general; each kind may be 'best' for a particular purpose, and the survey type has its own field of usefulness. In this field, as in any other, all degrees of quality are possible. On the one hand, survey studies may be so trivial, so poorly conceived or narrowly carried out, or so lacking in penetrating analysis, that they fail to rise above the level of clerical routine and can make no claim upon the name 'research.' On the other hand, one may exercise great ingenuity, skill and insight in planning and prosecuting his study so that it not only serves its immediate purpose but may also serve to set new standards in the area involved."

[4] Good, Barr and Scates, *ibid.*

A DEFINITION OF SCIENCE EDUCATION: CURRICULUM RESEARCH *

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Science education is here defined in terms of research related to the curriculum, the "what to teach" concerning the world of nature. It can be called the organized instruction through which our society attempts to direct youth in its understanding of, and its self-orientation to the material universe. It is concerned with both overt and implicit adjustments of youth to themselves, to their environment, and to their neighbors, both immediate and around the world. Curriculum can have many meanings; it is here used in the sense of "what to teach." But the natures of science, youth, society, learning, and of the environment being what they are, "what to teach" can hardly be considered seriously without examination of related aspects of why teach, how to teach, with what facilities, and toward what changes in the learner.

Curriculum so conceived is not indifferent to factual recall of names, places, and formulas, or of specific statements of relationships; but its primary concern is with personal integration into a pupil's own thinking, of concepts and principles of nature—this to be evidenced by behaviors involving use of the concepts and principles, or at least by verbalization or writing of proposed uses in described situations.

Stated differently, the concern of the curriculum in science is to increase the pupil's capacity for adjustment, for finding and verifying solutions, often on a pedestrian level, but some times unique, original, creative. We disclaim interest in teaching merely the answers to today's questions. Time is not available, and many of the answers are unsure. For example, who knows how to avoid the common cold, or how to quit smoking?

But many are strongly committed to the ideal of a curriculum with built-in features to assure first hand acquaintance with science both as personal experience and as a social institution.

To *accept* such a purpose for curriculum is one thing; to find content, experiments, and other curriculum components to achieve it is *another matter*. This is where research comes in, though prior to research another essential aspect of science, namely measurement, probably should proceed at length and ingeniously. Herein also lies the reason for defining science education in terms of curriculum research.

Four approaches to curriculum have been used singly or in combination:

The study of society
The study of youth
The analysis of the environment
The analysis of science

The study of society furnished the rationale for early Nature Study in New York State, especially in the relations between the economic depression of 1890's and the goal of Nature Study of keeping youth on the farm through greater enjoyment of nature. It also can be seen in the report of the Committee on Reorganization of Science in the Secondary Schools in relating science instruction to the seven cardinal principles of education.

The use of analyses of society for curriculum making must be true to the fundamental values of society and requires insight into what society requires of each generation. It must interpret correctly the role of the individual in our society.

The attempts to guide education in line

* Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, February 24, 1961..

with the foregoing should, I believe, be essentially conservative. The unique competence of the teaching profession lies in making analyses of society and the role of the individual, and in orienting education thereto, not in revising fundamental values or in redirecting society.

The study of youth has provided a main current in the stream of thought about curriculum. The problems of adjustment approach to curriculum in science was elaborated at length by Pieper in 1932, and probably has had as extensive and as lasting influence as any proposal of the 31st yearbook. The analysis of the needs of youth and accompanying plan for using needs as the bases for curriculum in science was the major contribution of a distinguished committee on Science in General Education. Their recommendations appear not to have been widely reflected in subsequent courses of study and curricula.

In the elementary and junior high schools, the analysis of the environment has led to familiar curriculum topics or problems.

Analyses of science have had deep and lasting effects on curricula. Long defined to include organized knowledge of nature, science was seen by Dewey, Downing, Craig, Curtis, Obourn, Keeslar, and many others to include how scientists seek truth, with resulting familiar analyses of scientific method, problem solving, critical thinking, or process. Others elaborated more specific aspects of the scientific process, such as Hurlbut on forming hypotheses, and Obourn on recognizing assumptions. An affective aspect—scientific attitude—is also recognized, sometimes as a separate and often as a part of process.

Analysis of science led Downing and many others, including a distinguished large group at Michigan and lesser numbers at other centers to identify principles of science believed to be most important to curricula in science.

Helms designed and constructed laboratory equipment to teach specific principles, coming closer than most in relating research directly to specific curriculum components.

Pieper's analysis of science in relation to curriculum resulted in a listing of categories of overt behaviors which are related to objectives of science instruction.

It appears from the foregoing and from the literature that the study of youth has influenced considerably the curriculum in science, largely through examination of personal and social needs and through selecting and organizing science content to help youth adjust to the modern environment. Also it appears that analyses of the nature of science have had much more influence on science curricula, mainly in refining lists of principles suitable for inclusion in curricula. This is not intended to minimize the worth of the analyses of science as method and attitude, or process; rather, to deplore the apparently small effect on science curricula of this most important aspect of science.

At least three major deficiencies can be found in a definition of science education in terms of curriculum research to date.

First, the definition of science education is not clear. Details are lacking, including specific meanings of objectives. Statements of goals such as functional understanding of principles and growth in scientific method are relatively meaningless unless further defined, and ultimately defined in terms of specific behaviors. High sounding general objectives may inspire teachers to strive to do something worthy, but it would help if that which is considered worthy could have objective meaning.

Teaching processes themselves are inadequately defined. It is difficult to describe a lesson or learning activity so that it is clearly communicated to the reader. This takes time, facilities, and some language competence. But unless science teaching, good or otherwise, can be described and communicated, none of us can

share another's thoughts about science teaching, or know wherein we agree. Much more could be said about our lack of communication.

A second and also crucial weakness in science education as seen through curriculum research is the almost complete lack of research on the nature of learning as it can affect science teaching. We build curricula and proceed ultimately to specific lesson plans without validated criteria for judging the specific contributions of specific educational activities to specific objectives. We are not sure they should be called educational.

The need for help from scientists in the fields of behavior and psychology seems urgent.

A third inadequacy in the definition of science education from curriculum research lies in the lack of an overall plan of organization through the K-12 or K-14 years. Aspects of the environment have served as a basis for organization in grades K-9, possibly to the general satisfaction of authors of texts, curriculum committees, and the teaching public, but surely not with any basis in research.

Principles of science in the K-9 years and of the special sciences in senior high schools have served also, perhaps largely through absence of obvious alternatives. A new selection and organization of content in physics appears to be crystallized in a unique pattern for many schools. Courses in chemistry and biology are also shaping up. How these will affect the science curriculum, if any, for the general body of senior high school pupils is not known. It would appear that the need for general education in science is not changed.

Shall we expect successful new senior high school science courses to lead through the same sponsorship or otherwise to new curricula in science, K-6 or K-9? Can a curriculum be constructed with growth in science as process serving as the criterion for advancement of pupils through the program?

Can some combination of principles, adjustments to environment, needs of youth, theories of learning, and growth in critical thinking point the way to selection, organization, and sequence in science? Can the worth of educational practices be measured? What curriculum research is needed? What other research is indicated?

CRITERIA FOR GOOD EXPERIMENTAL RESEARCH IN THE TEACHING OF SCIENCE *

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EXPERIMENTAL research using the school or classroom as the laboratory or research in a specially constructed laboratory involves an attempt to control or account for all known essential factors save a single factor that becomes the experimental variable which is manipulated with a view to determining or measuring the effect of its operation.

Experiments may be absolute or comparative. In the field of teaching the experiments are most often comparative, that is two or more treatments or patterns are compared in terms of their effects on a chosen characteristic of the population.

The general procedure of scientific research is to define a problem, formulate hypotheses, and to verify or deny these directly or by their consequences. Although present emphasis seems to be on proving hypotheses to be true, it seems a more valid emphasis should be upon disproving

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hypotheses. That is the emphasis should be upon revealing the error of the creative idea rather than its virtues. If no denial can be ascertained its virtues become much more evident.

This verification (proof) or denial (disproof) of hypotheses necessitates the collection of observations germane to the problem. The observations to be made are to be relevant to the hypotheses and possess the potential of supplying an unambiguous answer to the problem.

It is these requirements that make the design of the experiment important. The design of the experiment relates the problem to the hypotheses and both to the nature of the observations. Thus it is obvious that the design determines in a large part whether or not the data have the potential of supplying an unambiguous answer to the problem.

The general principles of the experimentation without the involvement of statistical theory generally consist of the following:

1. *Statement of the problem.* This must be precise. In its early stages the problem to be studied or investigated is usually stated in general and at times indefinite terms. The precision of the statement increases as planning proceeds. The problem may be modified and restated repeatedly with the desire to improve its amenability to experimental attack in light of the equipment, subjects, or other available resources. The design of the experiment is determined to a large part by the precision of the problem. It is only through having problems succinctly stated that reliable answers can be secured.

2. *Hypotheses are formulated.* The researcher here should be somewhat of a free thinker. He should be informed of the past research in the area but not prejudiced thereby. Most hypotheses are based upon assumptions. Researchers should list their assumptions and subsequent hypotheses. This is especially important in experimental research.

3. *Design of the working plan or experiment.* Questions to be asked here are: (a) Is it possible to make objective observations that are unbiased estimates of true effects? (b) What degree of precision is desired? (c) What statistical treatment is to be given to the data to relate the data to the hypothesis and problem?

Involved are other vital procedural decisions that must be made prior to performance. There must be a description of the treatments to be given the experimental factor. These should be carefully and completely described so that other researchers can repeat your experiment. There should be descriptions of how the population was selected, what instruments were used for measuring and all other details relevant to the procedure.

Several type forms of experimental designs have been given to us. Not all designs can be used in any project. Several are listed for your information along with precautions or shortcomings.

1. One group or the treatments by subjects. This is an experiment in which two techniques, two factors or two treatments are successively administered to the same group of pupils.

There are many obvious difficulties here as: the temporal difference due to sheer passage of time and resulting increase in maturity, the factor of sequence of experiences, practice effects, encouragement or discouragement effects of preceding experiences, time of the year and general social events that may introduce errors into the results. This is, however, a very simple kind of experiment to design.

2. Simple randomized groups. In this design the treatment is administered to two or more groups selected at random from a total or parent population.

The assumption is that all the pupils of a given school, city or state are distributed in classes in a random manner or that individual pupils from a city or state are assigned to schools in a random manner. If this design is to be used recognition

must be given to the fact that school populations are not randomly distributed within limited populations. This is especially relevant when entire classes are to be utilized. Recognition is given here to statistical techniques that may be applied to rule out these differences.

3. Matched samples, parallel groups or treatments by levels. This is a specialized case of that previously described in that the groups or individuals are matched for some one or more relevant factors. The assumption here is that the groups or individuals will be more alike in response to the different treatments.

It is well to determine if possible what factors are related to the desired results by means of statistical techniques. Notice the term related rather than cause was used. Relationships may be temporal as well as cause and effect. Too often in educational research we find a statistical relationship and immediately dignify it with the position of cause and effect.

There may be times when individuals are grouped or equated on the basis of I.Q., mathematical competence, reading ability, visual acuity, past marks in science, English etc. or some combination of these. The prejudice in equating groups or individuals is great and the entire principle is in need of serious philosophic consideration.

4. Rotational groups. Here the same basic experiment is repeated (replicated) by means of the reversal of the groups at intervals. This is often used when parallel groups are not available or there is doubt of the equivalence of the groups in terms of initiative, social status etc.

Bias may enter here again as a result of temporal differences in experiences provided. i.e. does learning a before b take place most efficiently or does learning b before a?

5. Random replications. The same treatment is repeated (replicated) with several independent samples drawn from the same populations. The samples may be randomly selected or may be matched groups.

6. Factorial. This is used when there are two or more cross classifications of treatments or if the effect or interactions of two or more experimental variables are observed simultaneously. Care must be exercised here more especially to ascertain the nature of the data required and its method of treatment prior to the experiment.

7. Groups-within-treatments. The populations to be studied are believed to consist of a large number of finite groups and the treatment is administered to smaller independent random samples of the groups.

Within this working plan or design the nature of the observation and the observational instruments must be carefully and clearly defined. The results of an experiment are no more reliable than the data collected.

It must be stated that presently research in the teaching of science has approached an obstacle that must be overcome before future research in teaching methodology is of much value. The obstacle is that of measurement. In the immediate future some group of enlightened individuals must sit together to give definition to the high sounding terms being used with abandon by scientists, science educators and educationists alike. Some of these terms are: knowledge, methods of science, and scientific attitude. It is hopeless to dream of complete agreement, however, it is realistic to dream of a group agreement. When the terms can be defined or described instruments for their measurement can be developed. Present definitions or descriptions of the terms are confused and lack terseness. It is somewhat disconcerting to find teachers of an experimental area of intellectual endeavor, who reputedly know what they are searching for in the laboratory, who care so little about where they are going educationally. We must develop instruments that measure to a degree the goals of teaching science or refrain from repeating the goals.

In the working plan, when the experiment involves different methods or tools of

instruction, further precautions must be exercised. Teachers employing the newer methods or tools must become proficient in their use. A method or tool in the hands of the unskilled may fail because of the lack of effective administration or execution. Teachers not anxious to try new methods or tools may not do the method justice. Pupils must become accustomed to the different technique or tool so that a "halo" or "Hawthorne" effect is eliminated.

Tools and methods of instruction cannot be used in comparative experimental situations until the users have become skilled and proficient in their use. Tools and methods of instruction must be a factor in an absolute design before they can become factors in comparative design.

As research workers we must first know if a tool works at all before we can find out if it works better than something presently used.

Submitted for your consideration is the proposition that all comparative experiments involving changes in methodology or tools of instruction have a prologue describing the absolute value of the tool or method before a compartive study is reported. It is submitted because of the many reports on file today with a final statement "no significant difference." This "no significant difference" may be the result of lack of skill in handling a tool or method.

The final stages in the conducting of an experiment are routine. The experimental and statistical plans are then followed. Conclusions are stated with measures of reliability.

At all times recognition must be given to the fact that even clever statistical treatment cannot provide evidence of cause and effect relationships and cannot change unreliable data to reliable results.

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PROBLEM SOLVING TECHNIQUES IN TEACHING SECONDARY SCHOOL PHYSICS * †

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A LARGE amount of work has been done with problem solving as a way of learning, both science educators and educational psychologists have done significant work in this area. Most of this effort has been devoted to discovering what problem solving is and under what conditions it may be brought about. This study is an attempt to approach the problem from a different standpoint.

For effective problem solving to be accomplished by students in the schools, the teachers must know how to create an environment which will encourage problem solving. When teachers are asked why they do not use problem solving in their classrooms, they reply in a manner which indicates that they don't know how. They often comment that they would like to see other teachers use this way of learning so that they might know how it is to be done.

* A paper presented at the Thirty-Second Annual Meeting of the National Association for Research in Science Teaching, Hotel Dennis, Atlantic City, New Jersey, February 20, 1959.

† This study was conducted as part of the Science Manpower Project at Teachers College, Dr. F. L. Fitzpatrick, Director.

Implicate in the concept of problem solving is the idea that each problem situation is unique to the learner. If this is so, and all evidence indicates that it is, then no specific set of directions can possibly be prepared for using problem solving as a way of learning in any particular situation. This does not mean that teachers cannot be helped in using problem solving in their classrooms. There would seem to be a number of ways in which such help might be offered. For example a list of criteria for identifying problem solving when it occurs and suggestions for classroom organization to promote problem solving might be gathered and circulated. The Science Teacher Service Circular, "An Analyses and Check List on the Problem Solving Objective" that Ellsworth S. Obourn prepared in 1956 from some materials of Darrel Barnard's is an example of this approach.

Another way of approaching this problem is exemplified by the "Project for the Improvement of Thinking," which is being carried on by the Bureau of School Research of the University of Illinois. The basic idea here is to take problem solving apart and teach the students how to use or do the various steps and skills needed to solve problems. In such an approach the learner practices identifying problems, making hypotheses and so forth. There may be some value in this approach.

This project, as was said before, is an attempt to approach the problem differently. It consists in the main, of a number of examples and description of how problem solving is or might be used in the physics classroom and laboratory. The objective is to show teachers that problem solving can be used under existing class situations and to motivate them to try problem solving in their classrooms.

The study is divided into five chapters, the first is a discussion of the nature of problem solving and the conditions under which it is most likely to occur. The material in this chapter was taken, for the most part from the literature and to a lesser extent from personal experience and experience as reported by other teachers.

The bulk of the study consists of three chapters of histories of successful problem solving. The first of these three chapters, deals with problem solving that has arisen from chance or accidental occurrences. The second with problem solving as it occurs as a planned classroom activity and the third with problem solving in the laboratory. In the latter case, individual project work was not included although it certainly offers one of the most fruitful ways of engendering problem solving on the part of students. Dr. Norburn Felton of San Jose State College has recently completed a study of project work in high school physics which is expected to be complementary to this study in this respect.

The material used in these three chapters is taken from the literature, from personal experience, from informally reported experiences of other physics teachers and through interpretation of technique and approach. Sources are cited where appropriate in the study.

In the final chapter an attempt is made to examine methods whereby the teacher may evaluate his and his pupils success in the use of problem solving as a way of learning. Reference is made here to check lists, and to tests: commercial, and teacher made. Suggestions are also made concerning other methods of evaluating teaching and learning.

The following sample history is from chapter three of the study, "Problem Solving in the Formal Classroom:"

The Little Black Box

This device is clearly related to a particular subject area, i.e. electrical circuits. Many variations of the wiring may be made either to make the device more complicated or simpler, or just to make it different so that members of one class will not be able to help members of another.

The box is constructed with dry cells, light bulbs, and several switches. Any number of variations may be made in the wiring. In the

illustration in Figure 1, three single pole double throw switches are connected in such a manner that one bulb will light when one switch is up and the other down and the other bulb will glow when the switches are reversed in position. The third switch parallels one of the others and serves to complicate the problem. It is nearly impossible to discover the arrangement of wiring inside the box without a carefully thought out plan of attack.

When the little black box is used with a class several students will usually volunteer to explain how it works and be proved wrong by their fellows. After a period of trial and error the class is usually ready for a systematic approach which follows the problem solving approach pretty closely. Such a pattern as this might follow. If switch *a* is up and *b* is down, light *B* is on. Therefore, switches *a* and *b* are connected to light *B*. If switch *a* is down and switch *b* is up, light *A* is on. Therefore, switch *a* must be connected to light *A* when it is down and switch *b* when it is up. From this it follows that the switches are at least double throw switches. The argument for the rest of the circuit is similar. In order to understand such a circuit it would seem that the students would have to understand simple circuitry.

If the box were used before formal study of simple circuits, then the students would have gained an understanding of the necessity of knowing about circuits. If the box were used after such an introduction, then the ability to solve the box might be regarded as a test of the student's knowledge and understanding of circuits.

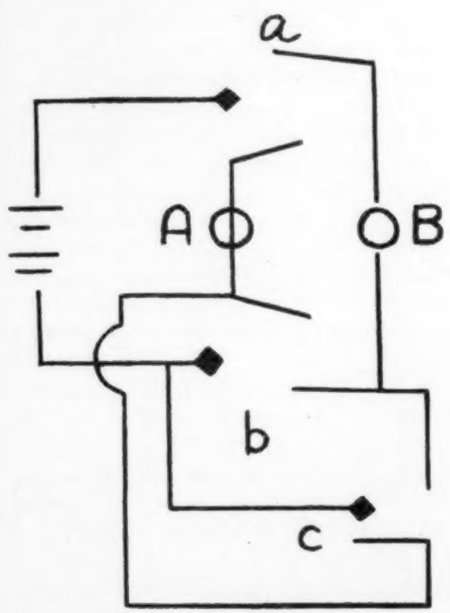

FIGURE 1

The next illustration is from chapter four, "Problem Solving in the Laboratory:"

Illumination

The usual method of teaching illumination consists of the teacher assigning the appropriate chapter in the text for the students to read and perhaps some problems for them to do. He then proceeds to discuss the concept and to demonstrate various kinds of photometers such as the Bunsen, the Jolly and the photo-electric. The important concept involved is: illumination varies inversely as the square of the distance of the illuminated surface from the source of illumination.

To develop this concept the problem solving approach may be used as illustrated in the following. The teacher demonstrated a Bunsen photometer and allowed the students to examine and use the device until they were satisfied that they understood what it was all about. Then he give the students directions for making a Paraffin block photometer.[1] The teacher then called the students' attention to the fact that the Jolly photometer when looked at from the side or top provided a means of comparing two light sources. This was the information that the teacher provided. The students were instructed then to take the device together with a supply of light bulbs, sockets and meter sticks and determine the relation between the distance from the source and the illumination on a surface.

Some of the students had read ahead in the text and discovered the statement concerning inverse square law. When they came and told the teacher what the relation was, he asked them how they knew, after they explained, he then asked them to demonstrate this relation. Other students worked with the apparatus until they perceived some sort of relationship. Some students decided that illumination and distance varied directly and were willing to write off the observed discrepancy as experimental error until the teacher insisted that they were wrong and that their data was correct. They then worked until they discovered the correct relation. Other students were at a total loss as to how to go about working with the apparatus they had on hand. The teacher helped them out by asking them, "if you put one 60 watt bulb one meter from the photometer, how far must you place two 60 watt bulbs to balance the one?" Many of the students gathered data but were unable to perceive any sort of relationship, although their data were quite close to the correct ratio. They

[1] A paraffin block photometer is constructed by placing a piece of opaque paper between two blocks of translucent paraffin that are the same thickness, in much the same way that a ham sandwich is assembled. The paper is held in place by melting the surface of the paraffin blocks and pressing them on the paper.

explained that the light did not seem to vary exactly as the square of the distance but rather in some sort of a more complicated manner. The teacher encouraged them to try to do the same procedure at different distances. After they had gathered more information, they were able to see the correct relationship.

At the end of the laboratory work, the group met in the classroom and the students gave their answer to the problem. The teacher, and the other members of the class followed the teacher's lead, insisted on evidence to support any assertions that were made. The teacher took particular care to point out to the class how they had gone about solving this problem.

The teacher then proceeded with a rather traditional discussion and demonstration involving the concept of the inverse square ratio and illumination, bringing in such topics as cameras and light meters.

At the end of the unit on light the teacher administered a standard objective examination. He found that his class knew and were able to apply the inverse square law. They also exhibited a good knowledge of facts concerning illumination. The teacher felt from the students subsequent work in the course, that they were more objective and able to find out for themselves.

The last illustration is similar to those found in the chapter on evaluation of problem solving. The actual material is available in a science manpower monograph.[2]

PRACTICAL TESTS

A class had been studying light, optics and optical devices. They had investigated the rules and laws of geometric optics and the nature of color and color vision. The problem solving approach had been used with a liberal supplement of lecture and reading assignment. An example of laboratory work from this unit appears earlier in this paper.

In the process of evaluation the students were given an objective test and were also instructed to pass through five stations of a practical examination.

The first station consisted of 3 pieces of yarn, one red, one blue and one green; and 3 colored filters. Each filter was associated with a piece of yarn such that the yarn appeared black when viewed through the filter. The student was asked to explain what he saw.

The second station consisted of an optical bench and a collection of convex and concave lenses, the students were asked to construct a telescope on the bench from the materials on hand. There were two such stations in parallel. A time limit of 4 minutes per person was set at this station.

The third station was a concave mirror and a rule. The students were asked to determine the radius of curvature of the mirror. They were not allowed the use of any other apparatus.

The next station, the fourth, consisted of a number of filters of various colors none of which was green and a small light bulb. The students were asked to select a combination of filters such that when they were placed before the bulb, the bulb would appear green. They were then asked to explain the function of each filter in the pack which they prepared. There were a number of possible combinations at this station, several of which the instructor had not realized were present.

The final station was a simple Kalidoscope, which had not been discussed in class, the students were asked to explain its operation.

In review of these five tests of a student's ability to solve practical problems having to do with light and optics, a few comments may be offered. The various stations were deliberately designed to be of differing degrees of difficulty. The first item was of such a nature that most of the students were able to do what was called for. The telescope proved to be too hard a problem for most of the students within the time allotted. The other problems proved to be somewhere in between these two in difficulty.

When setting up evaluation instruments such as these, the teacher must be ready

[2] Peter Dean and Lester Mills, *The Problem Solving Method of Teaching.* (New York: Bureau of Publications, Teacher's College of Columbia University, 1960).

to make modifications according to the ability and attitudes of a particular class.

The author has made use of this material in his teacher training classes at Wayne State University. Students are told of these successful problem solving experiences and of others in different fields and are then asked to develop problem solving situations in their student teaching or teaching situations and report back on them to the class. It is possible to check on the relative success of these experiences with the critic teachers and in this way develop an expanded collection of successful problem solving situations which in turn will be used with future students.

THE STUDY OF NEW DEVELOPMENTS IN SECONDARY-SCHOOL SCIENCE—GRADES 7–12 * † ‡

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THERE is no specific formula for developing the new secondary science courses which our times require, nor are their readily available descriptions of promising programs in various parts of the country to assist teachers, administrators, and other groups looking for help. Questions relating to courses for talented and science-interested children, to how successful biology courses are at the ninth-grade, to the status of general science, to problems and patterns of homogeneous grouping, to vocational science courses for those not college bound, to problems in scheduling laboratory and recitation time, to use of community resources, and to in-service training of teachers are asked and there are no ready answers.

THE PURPOSES

Answers to some of the foregoing questions and others raised by those endeavoring to improve science instruction are being sought. The purposes of the present study, stated briefly, were (1) to bring to light new and promising junior and senior high school science programs, and (2) to present this information in a form in which planning-groups can readily use it.

Although the present study was not intended to substitute for larger, long-range studies, it may indicate areas for further investigation.

The data collected were descriptive in nature. No attempt was made to make a statistical analysis of the frequency of specific types of science courses in effect, of the numbers of students enrolled, of the amount of time devoted to laboratory activities, of teacher preparation, or of facilities available for science instruction. Nor was an attempt made to evaluate the new developments reported.

THE METHODS

An *ad hoc* committee met to define the purposes of the study and to outline the procedures to be followed. This group named an Advisory Committee to assist with the plans for the study, including the form of the questionnaires for securing information concerning new developments in high school science teaching.

A somewhat larger Field Committee, consisting of key persons from various

* The study was made possible by a grant from the Shell Companies Foundation, Incorporated.

† Based on "New Developments in High School Science Teaching," 108 p. $1.50. National Science Teachers Association, 1201 Sixteenth Street, N.W. Washington 6, D. C., 1960.

‡ Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 24, 1961.

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parts of the country in touch with high school science developments, was named to suggest schools to be included in the investigation. Letters were sent to members of the Field Committee requesting the names of schools and school systems which would be the sources of information concerning new and successful courses and administrative procedures.

A questionnaire was sent to each administrator named by the Field Committee asking him to give the name of the teacher or supervisor best qualified to describe the promising new development. A second questionnaire was sent to the teacher or supervisor named to secure desired details. The raw data for the study consisted of completed questionnaires, courses of study, and other published materials.

FINDINGS

General Science Courses

The three-year junior high school science sequence is still far from universal. No consistent pattern could be noted in the programs included in the study. But, in spite of the variations which were found, a number of trends were evident.

There is a movement to offer general science courses stressing academic content in order to provide an adequate basis for senior high school science courses. In fact, a number of schools have general science programs with units in introductory biology, chemistry, and physics. This increasing academic rigor is accompanied by demands for greater proficiency in mathematics. It is apparent, from the schools included in the study, that courses in which science is integrated with social studies in a core program are no longer being introduced.

More time is being spent in individual or group investigations in the form of projects, laboratory work, or "home experiments." Increasing use is being made of community resources in these student investigations. Scientists are coming into the classroom and students are going out into scientific installations in the process of finding answers to problems. After school, Saturday, and summer programs provide time in addition to that regularly scheduled for general science for investigative activities.

Ability grouping is increasing. A three-track science program is not uncommon and a five-track program was reported by one school. Courses in biology, earth science, or physical science are frequently part of these multi-track programs—especially at the ninth-grade level.

Many persons called upon to teach general science are not secondary science specialists. As junior high school science programs are being strengthened academically, an attempt is being made to enrich subject matter backgrounds of teachers through in-service programs and attendance at summer and academic year institutes.

Earth-Space Science Courses

Earth-space science, consisting of elements of astronomy, geology, meteorology, and paleontology, is becoming a popular ninth-grade offering—especially for those of greater than average ability. These courses are not the "watered down" general education courses of twenty years ago. The typical modern earth-science course has open-ended laboratory and field activities, contributes to an understanding of basic physical science principles, and meets college entrance requirements.

Schools offering earth science encounter the problems presented by any new course. One of these is the difficulty of securing qualified teachers; the other is the lack of adequate teaching materials. Both difficulties are being remedied. Undergraduate and in-service programs for training earth science teachers are beginning to be

offered. New textbook materials are in preparation and supply catalogues are showing apparatus for laboratory work in earth science courses.

The American Geological Institute, under a grant from the National Science Foundation, rendered the earth-science movement an important service by preparing a sourcebook of subject matter for earth science courses, by cataloguing and evaluating teaching materials, and by preparing and testing field and laboratory procedures.

Biology Courses

Biology, formerly offered almost exclusively at the tenth-grade level, is now commonly taught in the ninth grade. The ninth-grade course is most commonly found in schools with more than one science track and is usually offered to students of greater than average ability and interest in science. Placing biology in the ninth grade enables students, who elect, to complete a four-year science sequence or to take additional subjects in other fields. However, in spite of its popularity as the ninth-grade science subject, the tenth grade appears to remain the level at which biology is most commonly taught.

An increased academic rigor is to be found in the high school biology courses recently developed by the Biological Sciences Curriculum Study of the American Institute of Biological Sciences, the School and College Study of Admission with Advanced Standing, and the Science Manpower Project. The new biology courses included in the present study at both lower and upper high school levels seemed to place greater stress on principles of biological science and less on technological applications than older high school courses. The approach, reflecting recent trends in research in the biological sciences, is apt to be biochemical in nature, rather than phylogentic or anatomical.

Each of the three versions of the Biological Sciences Curriculum Study course prepared in the summer of 1960 makes a different approach to biology. One emphasizes the biochemical basis of life, another emphasizes the ecology of organisms, and the third is more traditional in nature. Laboratory manuals for the three BSCS versions were prepared at the same time and, to go one step further in revitalizing high school biology, a "block" approach to laboratory experience was developed. A block requires four to six weeks of class-time devoted exclusively to the laboratory study in depth of a problem area permitting development of a sense of the processes of science. These materials are currently being tried out in biology classrooms of over 100 high schools in the country. Revisions will be made in the light of tryout experiences. A testing program is being developed by Educational Testing Service in order to determine whether the course is accomplishing the goals originally set up. Films, monographs, materials for academically talented students, and teachers manuals are also being prepared for the BSCS courses.

For some ten years high schools have been offering courses under the arrangements of the School and College Study of Admission with Advanced Standing. These courses are local modifications of the basic courses recomended by the high school and college teacher committees in half a dozen subjects. Topics are recommended for biology, chemistry, and physics as well as for non-science courses.

These courses are designed to provide either advanced placement, college credit, or both, on the basis of results of the College Entrance Examinations Board's Advanced Placement Examinations. Courses may be taught as either first- or second-year courses; most of these biology courses included in the study were second-year courses. College textbooks are used and a high degree of scholarship is required. The biology courses in this program do not differ markedly from college biology courses.

Those concerned with instruction in the biological sciences will be interested in the Continental Classroom series to be televised on a nationwide basis beginning in September 1961.

Several advantages are to be gained from using a course in biology, chemistry, or physics prepared by a nationally recognized national committee. One is that a course of study has been outlined, at least in terms of main topics, which meets the approval of a group of outstanding scientists and educators. Another is that the success of the course, in terms of student achievement, is measured by a standardized examination. A third is that there are inservice programs for preparing teachers to offer these courses. And finally, the name of the course has meaning to college admissions officers.

Biology electives include those especially designed for students planning medical-science careers. Courses in microbiology, botany, zoology, field biology are also popular. Biology seminars place emphasis on development of research techniques through advanced projects, reading of originals of scientific treatises such as Darwin's *Origin of Species by Natural Selection* and Harvey's *Motion of Heart and Blood,* and consultations with scientists.

Chemistry Courses

Newer chemistry courses differ from traditional ones in stressing theory, rather than descriptive materials and technological applications. In addition, quantitative aspects of the subject occupy more time than previously and there is increased emphasis on modern topics.

About half of the chemistry courses based on the recommendations of the School and College Study of Admission with Avanced Standing were first-year courses and the other half, second-year courses. College textbooks and laboratory manuals were used in these courses. Frequently course prerequisites included biology, chemistry, and physics, as well as three years of mathematics. In some cases, before- and after-school hours were used to provide for completion of long laboratory assignments. Open-ended experiments were preferred in the laboratory programs.

The Encyclopaedia Britannica high school chemistry course on film, and the nationwide television course, *Continental Classroom—Modern Chemistry,* both taught by Dr. John F. Baxter of the University of Florida, and both produced under the supervision of advisory committees appointed by the American Chemical Society, represent modern introductory chemistry courses in both presentation and content. Each involved extensive revision and updating of the classical chemistry course format. *Modern Chemistry* was intended to bring teacher's knowledge of the subject matter of chemistry up to date. The content of the film series included modern aspects of chemistry—the mole concept, bonding, the Bronsted-Lowry theory, biochemistry, and the packing of spheres. One state university televised *Modern Chemistry* as part of its extension division services to nearby high schools without chemistry teachers. The extension division supplied kits for schools without laboratory facilities, a film guide, sets of tests with keys, text references, work sheets, laboratory activities, and consultation sheets. The university offered similar services for a televised physics course.

The Chemical Bond Approach to teaching chemistry, supported by the NSF, was tried out in nine high schools during the 1959–60 school year. Revision of the materials and additional try-outs will further refine the materials.

The CBA project holds that chemical bonds are the logical central theme for a meaningful high school course. Considerable attention is given to the relations between the geometrical properties of the underlying structure of a substance and observable physical and chemical properties.

The Chemical Education Materials Study project stemmed from an *ad hoc* committee appointed by the American Chemical Society to study the need for, and possibility of, revising the chemistry course at the high school level. The committee recommended that a course content study be initiated.

The textbook and laboratory manual have been edited and revised and are being used in a number of schools during the 1960–61 school year. Films and supplemental monographs will be prepared for use in the course.

The heart of the CHEMS course is its experimental approach. A new topic is usually introduced through experimentation which is integrated with the text. The course is organized around theories and principles, with facts used in substantiation of the theories.

Although the chemistry projects of the School and College Study of Admission with Advanced Standing, the film courses, and the CBA and CHEMS projects have a common aim—improvement of instruction in chemistry—they approach this goal from different angles.

Physics Courses

The physics committee of the School and College Study of College Admission with Advanced Standing recommends a list of basic topics for high school advanced standing physics courses. This list includes the traditional physics topics—mechanics, heat, electricity and magnetism, and atomic and nuclear physics. The committee favors study in depth of the fundamentals of these topics, rather than a superficial consideration of all aspects of the subject.

To attain study in depth, the committee suggests that approximately fifty per cent more time than usual be spent on the subject. A college textbook and laboratory manual are recommended and it is expected that the students have a strong background in mathematics including trigonometry and the use of the slide rule.

Another physics course, developed by the Physical Science Study Committee of Educational Services, Incorporated, was first offered experimentally in 1957–58. The PSSC course is essentially a modern one, emphasising the quantum approach and wave mechanics. Part I of the textbook deals with the universe; Part II, with optics and waves; Part III, with mechanics; and Part IV, with electricity and atomic structure. Correlated teaching materials include a laboratory guide, a set of new and inexpensive apparatus, a series of films, standardized tests, a series of paperback monographs, and a teacher's resource book.

Introductory Physics is the title of a complete physics course on film. It consists of 162 thirty-minute filmed lecture and laboratory lessons. An assignment guide, a teacher's manual, and a testing program accompany the series. Teachers and supervisors using this film series found that inflexibility of the schedule, difficulty in keeping up with the pace of the series, and covering materials at the expense of study in depth are among the disadvantages of using a long film series. Administrators, however, realize the advantages in having a course on film when a qualified teacher is not available.

Atomic Age Physics, the Continental Classroom television physics series developed primarily for teacher-training purposes, has been used successfully in a number of secondary schools. Early morning viewing at home or in school, followed by a student-teacher discussion in school, was the usual pattern of procedure. The series was supplemented by reading and problem assignments from standard physics textbooks, and recitations and laboratory work done in school.

Physical Science Courses

Ten to twenty years ago, the term "physical science" was almost synonymous with "senior science" and "consumer science." The course was taken in the elev-

enth or twelfth year by students who did not have enough ability to succeed in chemistry and physics courses. Like general biology courses, it was terminal in nature. Although it provided credit toward high school graduation, it usually did not meet college entrance requirements for a year of laboratory science. Content included materials on home appliances, textiles, driver education, and industrial processes.

Such courses are still being taught, but today a new type of physical science course is becoming popular. The subject matter still contains elements of chemistry and physics. But here the resemblance ends. The new course is an academically sound one for students of greater than average ability. The objective is an understanding of major principles of physical science, rather than a knowledge of the technology of science. Mathematics standards for these courses are generally high.

The physical science course may be offered as a ninth- or tenth-grade subject enabling students of above average ability to begin college-level work in physics and chemistry in their junior year. Rather than crowd the subject matter of the two disciplines into a one-year course, however, a number of schools prefer a two- or three-year sequence. The success of the two-year course is attested to by the fact that a textbook has been published for it.

There are a number of things in favor of the physical science course. Duplication of such topics as atomic structure, the states of matter, and the gas laws is eliminated. In addition, learning studies indicate that both immediate and delayed recall in the strong physical science course is greater than in a two-year sequence of traditional chemistry and physics courses.

Seminars

Science seminars have a number of characteristics in common. They help break down boundary lines among the sciences, they provide time for individual research-type work, and they present greater opportunity for providing for individual differences.

There is no single pattern for seminars. Some are an integral part of the school science program; others, sponsored largely by persons outside of the school, have objectives which may or may not be educationally sound. Some seminars make extensive use of community resources in the form of speakers, consultant-teachers, library and laboratory facilities, and even financial support. Others are relatively school-contained. Science seminars run the gamut from highly organized courses with textbook assignments, regular reports on reading and research, and instruction in statistical and research techniques to those which are merely unstructured student-project periods. Seminars, once limited to the eleventh and twelfth grades, are now popular in the junior high school as well.

Using Out-of-School Hours, Facilities, and Personnel

Many persons have felt that school facilities and student time should be used to greater advantage. This is being accomplished in an increasing number of schools by extending the science program beyond the normal school day.

Educational programs such as those of the Continental Classroom televised in early morning hours have provided the stimulus for a number of before-school programs. Viewing at home or at school may be followed by student discussions and activities appropriate to the televised topic. Textbooks and a TV lesson schedule are available for most of these courses.

A number of science programs have been scheduled to extend beyond the beginning or end of the normal school hours in order to provide for the three- or four-hour laboratory period typical of college science courses.

In some parts of the country the schools have not always been able, because of small size, lack of trained science teachers, or suitable laboratory facilities, to offer science courses. The extension division of one university has been able to combine a TV presentation of the films with a correspondence course, providing laboratory kits for standard experiments, assignment sheets, and problems.

Evening, Saturday, and summer science courses and seminars have made it possible for high school students to profit from use of university and industrial laboratory facilities and from the experience and training of research scientists. Evening courses may meet as often as once a week or as infrequently as twice a semester. Sessions for these evening, Saturday, and summer programs have ranged from formal lecture programs by research scientists to informal periods providing time for scientists to advise student investigations.

In some seminars, students were highly selected; in others, they volunteered. In some schools a fee was charged; in others, the program was free.

Most of the out-of-school programs were for eleventh- and twelfth-grade students, but there were a number for junior high school groups.

In Rochester, New York, Washington, D. C., Oklahoma, the New England states, and other localities, scientists have organized for the purpose of giving the utmost assistance to school science programs. Methods of aid include providing a registry of speakers and consultants, publication of a local science newsletter, and arranging for student tours and work experiences.

The idea of providing a summer science work program is not new. A leading marine biology laboratory has had such a program for a number of years. Never before, however, have there been so many summer opportunities for able high school students to learn. The National Science Foundation, to name but one organization, during the 1961 summer provided nearly 7,000 students with the chance to obtain partial financial support for science training in cooperating colleges, universities, and other research centers.

There are two general types of summer science training programs. One stresses lectures, supervised study of assigned materials, and laboratory and field work. The other provides real work experience on a specific research project under the guidance of scientists. Still other programs combine the two types of activity just described in varying proportions.

CONCLUSIONS

1. Content of the new high school science courses included in the study is more rigorous and reflects recent developments in the respective scientific disciplines.
2. Quantitative aspects of science are stressed and mathematics prerequisites are increasing.
3. A majority of the new courses are for high school students of above average ability and interest in science.
4. Ability grouping was reported by many of the schools included in the study. A three-track program is not uncommon, and one school reported five tracks.
5. There is increasing stress on laboratory work, especially laboratory activities of an open-ended nature.

ERRATA

Dr. William W. Cooley has asked *Science Education* to make the following statement: "An error has been found in the Cooley-Bassett article which appeared in the April, 1961 issue. In Table I, page 211, the standard error of the difference between FAS Part II means should be $\sqrt{.213}$ or .461 rather than the .213 reported. The remaining calculations are reported correctly."

EXPERIMENTAL STUDY INVOLVING THE COMPARISON OF TWO METHODS OF PERFORMING EXPERIMENTS IN HIGH SCHOOL CHEMISTRY * †

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The Background of the Study

THE American youth of today faces a more complex world, and one to which he must adjust in a shorter period of time than the youth of a generation or two ago. He is living in a fast moving age in which many strong forces are tending to produce changes rapidly. These changes are often caused by advances of technological or scientific nature. Judging by trends as evidenced in the past several decades, it seems reasonable to assume that the forces of science and technology will play an increasingly vital role in the lives of all American youth. This being so, it becomes the function of the schools to offer science courses that will help students to adjust to these changes, and to present these courses in such a manner as to stimulate learning through processes which are more meaningful, more rewarding, and more challenging.

Need for this Study

There exists a need for the re-evaluation of the secondary school science curriculum to determine whether different methods of teaching during chemistry laboratory periods can be more meaningful, more rewarding, and more challenging.

This need for re-evaluation exists in light of:

(1) The present school population that enrolls in science courses in the upper grades has experienced a richer science program than the school population of years ago. This has been brought about by such factors as: (a) More organized science is taught in the elementary grades. (b) General science is well established at the junior high school level. (c) Students are learning more science from such sources as radio, television, magazines, and newspapers. (d) Eleventh and twelfth graders acquire valuable science experiences in such courses as health, consumer science, geography, or physical science before taking chemistry.

(2) More content is being added continuously to secondary school science courses. In spite of chemistry books and laboratory manuals becoming more voluminous, many administrators are finding it necessary to decrease the length of laboratory periods. Such trends indicate a need for re-evaluation of the procedures used during laboratory periods.

(3) Current writings by educators and science teachers indicate an existing need for an investigation into laboratory procedures. Many science teachers are anxious to give students science experiences that are more meaningful, rewarding, and challenging than the ones they are experiencing at present. The instructors feel that high school students are not deriving maximum value from their laboratory experiences. These instructors are not positive what other laboratory methods, if any, would produce more favorable learning results than those produced by the traditional method of teaching during laboratory pe-

* Paper presented at the Thirtieth Annual Meeting of the National Association For Research in Science Teaching, Hotel Claridge, Atlantic City, New Jersey, February 15, 1957.

† Based upon Dissertation with same title, submitted to the Faculty of the Graduate School of the Pennsylvania State University in 1958 in partial fulfillment of the requirements for the Degree, Doctor of Education.

riods. This study was executed to answer the above statement.

Hypotheses Tested

These hypotheses were tested:

1. There is no significant difference between the students taught by the experimental method and those taught by the control method in the mastery of unrelated facts, principles, problems, equations, and symbols of chemistry.

2. There is no significant difference in the abilities of students to interpret chemistry knowledge stated in the form of graphs, tables, paragraphs, and diagrams of experiments between the students taught by the control method and those taught by the experimental method.

Procedures Used in the Study

The study consisted of selecting at random six different high schools located within an approximate radius of thirty miles from Kent State University in Kent, Ohio.

In each of the six schools, two groups participated in the study, namely: the experimental group with a total of 125 students, and the control group with a total of 116 students.

The control group consisted of students who performed ten chemistry experiments *according to directions found in most present laboratory manuals.* The experiments were selected by experienced secondary school chemistry instructors. Each instructor discussed with this group the ten experiments and the textbook content related to them *before they were performed in the laboratory.* The students recorded their results *on the blanks provided for this purpose in the manuals.*

The experimental group consisted of students who *devised methods of solving problems given to them before a discussion of that particular phase of work in the classroom.* The ten problems or experiments were identical to those given to the students in the control group. *They recorded their results on special experiment sheets in the form of observations, equations, calculations, diagrams, and conclusions.*

During the latter part of January in both 1955 and 1956, this study was started in one of the six schools. These two years served as "pilot-study" years in preparation for an identical study in six schools during January of 1957 through May of 1957.

Previous to the actual commencing of the study, statistical data have indicated that:

1. The instructors who participate in this research were significantly similar in their training and teaching abilities.

2. Both the schools and the communities were significantly alike.

3. The textbooks, laboratory manuals, and laboratory facilities were significantly similar in all six schools.

4. The mental abilities of the students in each of the two groups in the twelve classes were significantly alike as measured by intelligence tests, teachers' marks in academic subjects, and chemistry aptitude scores.

After the ten experiments were performed by both groups during the second semester, the Cooperative Chemistry Test, Form Z,[1] was administered to each of the two groups in the six schools. The two parts of the test were given to verify the hypotheses mentioned previously.

Findings and Interpretations

When the two groups were compared on the results of Part I of the chemistry achievement test, the critical ratio revealed that both groups performed equally well in the mastery of unrelated facts, principles, problems, equations, and symbols of chemistry regardless of the procedures

[1] J. F. Castka, *et al. Cooperative Chemistry Test Form Z.* Princeton, New Jersey: Cooperative Test Division, (1950), 8 p.

used during laboratory periods. In light of this evidence, it would seem unwise for an instructor to spend additional time preparing special experiment sheets, gathering additional references, providing a variety of equipment, and to spend additional class time in the preparation of experiments.

Part II of the Chemistry achievement test, which measured students' abilities to interpret chemistry knowledge stated in the form of graphs, tables, charts, paragraphs, and diagrams of experiments, revealed that students in the experimental group did significantly better than the students in the control group. The critical ratio for this part of the test showed that the students in the experimental group would do better 98 times out of a 100 in the interpretation of chemistry knowledge expressed in the form of graphs, tables, charts, paragraphs, and diagrams of experiments, than the students in the control group.

In the light of this evidence, it would seem advisable for an instructor to use the procedures of the experimental group if he and his students are interested in the development of the characteristics of the scientific method.

ANALYTIC SURVEYS *

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MANY studies in education or science education employ a method known as the normative-survey, where the purpose is to obtain a description of the status of such variables as semester hours of preparation in science of science teachers or the reactions of administrators to a list of supervisory activities. Thus the data obtained may be qualitative or quantitative in nature and the subsequent analysis of the data may lead to descriptive and inferential or sampling statistics. When the concern of these studies is only with status, little is added to the decision-making process. On the other hand, if the concern of these studies is with the adequacy of the status, the process of decision making is augmented.

An excellent illustration of the normative-survey type of study resulting in descriptive statistics was that of Pella's,[1] where the purpose was to describe the nature of the academic preparation in science of Wisconsin high school teachers. To quote the author:

> The concern of this study is not with the adequacy of the preparation but rather upon the nature of the academic preparation of the science teacher in Wisconsin.[2]

When such is the purpose of a survey study, the results are statements such as the following:

> The average teacher of chemistry has an average of 18.5 credits of chemistry in his preparation.[3]

Pella's study was a comprehensive one since it involved 258 physics teachers, 367 biology teachers, 261 chemistry teachers, and 407 general science teachers. No mention was made in the report as to whether the 261 chemistry teachers constituted all of the chemistry teachers in Wisconsin or whether the sample of 261 was representative of all of the chemistry teachers in Wisconsin. Thus, any statement about the average chemistry teacher refers only to the sample involved and no inference can

* Paper presented at the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching, Pick-Congress Hotel, Chicago, Illinois, February 24, 1961.

[1] Milton O. Pella, "The Nature of the Academic Preparation of Wisconsin High School Teachers of Physics, Chemistry, Biology, and General Science," *Science Education*, 42 (March, 1958), 106–137.

[2] *Ibid.*, p. 106.

[3] *Ibid.*, p. 127.

be made to the larger sample of all chemistry teachers in Wisconsin. It may be that the sample included almost all of the teachers or was representative of all teachers. The report gave no indication regarding these facts.

An earlier study by Anderson [4] had the following purpose:

> A description of the practices in the teaching of biology and chemistry current in the school year 1946–47, and a description of the persons who taught these subjects in terms of preparation, experience, teaching loads, teaching objectives and professional activities.[5]

One descriptive statement in the study was the following:

> The median number of quarter hours of preparation in college biology for biology teachers was 27.[6]

Although this statement was a description of the 58 biology teachers in the sample, it may be inferred that the median number of hours of preparation was typical of all biology teachers in Minnesota. This statement is correct insofar as the sample was representative of the entire group of biology teachers in Minnesota. Barr, Davis, and Johnson had this to say about the sample in this study:

> Anderson selected a representative sample of 56 high schools in the state making use of the principle of proportionate sampling from schools stratified according to population centers.[7]

The author was concerned with the adequacy of the preparation of these teachers in that comparisons were made with prior studies made in 1923 and 1946.

Neither of the studies by Pella and Anderson were analytic but constituted legitimate research involving for the most part only descriptive statistics. An analytic survey and a normative survey may be similar in that both involve samples and both may be representative of specified populations. An analytic survey differs from the normative survey in one respect in that the purpose is to draw statistical inferences. This requires a carefully selected sample because one is concerned with a specified population of which the sample is a part. The sample, therefore, *must* be representative of the population. Barr, Davis, and Johnson have this to say about the sampling survey:

> The method of investigation by sample has for its purpose the description of the properties of an accurately defined population by means of information obtained from the sample. Sampling, that is, the selection of a part to represent the whole of a population, is a procedure of long standing and importance. It is indeed the most important problem in practical research. If there were no validity in the use of samples in scientific inquiry, investigations would be impossible unless the total population were studied.[8]
>
> The primary purpose of any sampling procedure is to obtain a sample which, within restrictions imposed by its size, will reproduce the characteristics of the population with the greatest possible accuracy.[9]

There are several methods of selecting samples such as unrestricted random sampling, stratified random sampling, and purposive selection. Only the second, stratified random sampling, will be illustrative. In his study of science teaching in Minnesota, Anderson had this to say:

> The problem was to determine the present status of science instruction in two fields in Minnesota secondary schools and to find what factors inherent in the pupil or in the teaching situation make for a better realization of the objectives of science instruction. The study was confined to the two secondary school sciences: biology and chemistry.
>
> The objectives of science instruction as reported in the literature on science education were coalesced into four about which the entire study was pivoted. These objectives were: acquisition of factual information in science, the understanding of the principles of science, the understanding and use of the scientific method, and the acquisition of scientific attitudes.
>
> Specifically, the present study had three pur-

[4] Kenneth E. Anderson, "The Teachers of Science in a Representative Sampling of Minnesota Schools," *Science Education*, 34 (February, 1960), 57–66.

[5] *Ibid.*, p. 57.

[6] *Ibid.*, p. 57.

[7] Arvil S. Barr, Robert A. Davis, and Palmer O. Johnson, *Educational Research and Appraisal*. J. B. Lippincott Company, Chicago, 1953, p. 184.

[8] *Ibid.*, p. 158.

[9] *Ibid.*, p. 160–161.

poses: (1) to determine those factors in the teaching situation which contribute most to the achievement of the objectives of science instruction; (2) to determine the relative contributions of factual information, understanding of principles, scientific attitudes, and intelligence, to the understanding of the scientific method; and (3) to describe the current practices in the teaching of biology and chemistry and to describe the persons who taught these subjects in terms of preparation, experience, teaching load, teaching objectives, and professional activities.

In order to draw conclusions concerning science teaching for the State of Minnesota, it is imperative that the schools participating in the study (the sample) be representative of the high schools of Minnesota (the population). In order to increase the accuracy and representativeness of the sample the method of stratified sampling (random samples from groups) was applied. In stratified sampling the population to be sampled is divided into groups or strata. Different numbers, proportional to the total numbers in each stratum in the population, are then selected from each stratum by some process of strict random selection within each stratum. If the strata are so taken that each constitutes a relatively homogeneous group, the accuracy of the sample will be considerably increased, because each stratum is represented in the correct portion in the sample.

The application of this sampling method to the problem proceeded as follows:

Step 1. In order to determine the strata from which each sample was drawn, it was necessary to determine the population of 461 population centers maintaining high schools in Minnesota in 1944–45. This was done by consulting the United States census figures for 1940. Thus there were 41 cities maintaining high schools in population centers under 5,000. Therefore it was decided to stratify the 483 high schools according to the following three categories:

Schools located in

1. Centers under 5,000 people (420 high schools).
2. Centers of 5,000 people or more (38 high schools).
3. The three big cities (25 high schools).

The school was, therefore, the sampling unit.

Step 2. The second step was to select a sample of schools in proportion to the numbers 420:38:25. Thus 87 per cent of the schools should come from population centers under 5,000 people, eight per cent from population centers of 5,000 people or more, and five per cent from the three big cities.

Step 3. Then, by using Tippett's "Random Sampling Numbers," schools were drawn according to the following procedure: An attempt was made to draw schools as closely as possible to the ratio of 87:8:5. Schools were contacted by letter asking them to participate. One restriction, that they offer both biology and chemistry, was imposed on the schools to whom the letters were sent. With few exceptions in the larger sized towns, the schools chosen by random selection did participate in the study. The final sample drawn contained 56 schools offering both biology and chemistry. The total number of students involved in the biology portion of the study was 1,980 and the total number of students involved in the chemistry portion of the study was 1,352. It must be pointed out that there was a slight disproportionality of schools from the larger cities in the total sample. This must be taken into account when the generalizations of the study are considered. The ratio thus became 86:10:4, whereas the planned ratio was 87:8:5.

Once a representative sample was obtained as described above, it became possible to make several statistical comparisons. Barr, Davis, and Johnson report the following about Anderson's study:

Through extensive use of the techniques of analysis of variance and covariance he made fourteen comparisons in biology and fifteen in chemistry which resulted in the identification of those teacher characteristics, pupil factors, and teaching procedures which were significantly as-

[10] Kenneth E. Anderson, "A Frontal Attack on the Basic Problem in Evaluation: The Achievement of the Objectives of Instruction in Specific Areas," *Journal of Experimental Education,* 18 (March, 1950), 165–174.

TABLE I

ANALYSIS OF VARIANCE AND COVARIANCE OF FINAL SCORES WITH OTIS SCORES AND PRE-TEST SCORES CONSTANT—SCORES OF STUDENTS TAUGHT BY TEACHERS WITH DIFFERENT AMOUNTS OF TRAINING IN SCIENCE

Source of Variation	d.f.	Sum of Squares	Mean Square	F	Probability	Hypothesis Tested*
Within Groups	174	12,082.0802	69.4372	....	......	....
Between Groups	1	591.7627	591.7627	8.52	P>.01	Rejected
Total	175	12,673.8429	....	....	......	....

* The null hypothesis, that there was no differenec between the means holding intelligence and pre-test scores constant, was tested.

TABLE II

ADJUSTED METHOD MEANS—COMPARISON

	Mean			Difference from Grand Mean						
	Otis	Pre-test	Final	Otis	Pre-test	b_1	b_2	Corr. b_1	Corr. b_2	Adjusted Mean
Group A*	43.703	32.890	49.726	−.142	1.014	.592652	.536072	−.084	.544	50.19
Group B*	43.200	36.500	47.240	.361	−2.596			.213	−1.392	46.06
Grand Mean	43.561	33.904	......	....	.....	....	....	....	.....	.....

* Group A was taught by thirteen teachers who had taken 77 or more quarter hours of science in college.
Group B was taught by thirteen teachers who had taken 32 or less quarter hours of science in college.

sociated with student achievement. *The survey evidence provided a valid basis for generalizations, characterizing the effectiveness of teaching biology and chemistry in the state.*[11]

An illustration of the type of analysis carried out using the technique of analysis of variance and covariance is given in Tables I and II.[12]

In another comparison[13] dealing with the evaluation of the achievement of students in biology in accordance with the amount of laboratory instruction received, there were thirteen schools in which pupils received 60 or more hours of laboratory work and thirteen schools in which pupils received 12 or less hours of laboratory work. An F value of 26.52, significant at the 1 per cent level, was obtained which indicated that a significant different between the adjusted means of the two groups existed. The first group had an adjusted mean of 55.08 and the second group had an adjusted mean of 52.34. That is, students in biology classes exposed to 60 or more hours of laboratory work achieved on the average significantly more than did the students in biology classes exposed to 12 or less hours of laboratory work. Through the application of the technique of analysis of covariance, the final means were adjusted for whatever inequalities existed in the two groups with respect to intelligence test and pre-test scores.

Another study which may be classified as an analytic survey was that by Anderson, Page, and Smith.[14] Reference will be made only to the purposes and the sample chosen for study. The purposes of the study were:

1. To determine the percentages of seniors designated as exceptional in science achievement in both male and female categories.

[11] Arvil S. Barr, Robert A. Davis, and Palmer O. Johnson, *op. cit.*, p. 184.

[12] Kenneth E. Anderson, *op. cit.*, p. 168.

[13] *Ibid.*, p. 170.

[14] Kenneth E. Anderson, Tate C. Page, and Herbert A. Smith, "A Study of the Variability of Exceptional High School Seniors in Science and Other Academic Areas," *Science Education*, 42 (February, 1958), 42–59.

2. To determine the relative contribution of schools of varying size to the exceptional groups in science achievement.

3. To obtain the degree of relationship existing between science achievement and achievement or ability in the other four areas for the groups designated as exceptional in science achievement. The other four areas were mathematics, social studies, English, and intelligence.

4. To describe the variability in science achievement of those seniors designated as exceptional in achievement or ability as measured by the other four tests.

5. To describe the variability in achievement or ability as measured by the other four tests of those seniors designated as exceptional in science achievement.

The sample was described as follows:

During the school year 1951–52, a representative sample of 1,445 Kansas high school seniors took the following tests: (1) *Essential High School Content Battery*,[15] and (2) *Terman-McNemar Test of Mental Ability, Form C*.[16] The achievement battery consists of four sub-tests designated as Science, Mathematics, Social Science, and English. The original sample of Kansas high schools, from which the data for this study were obtained, was selected by means of stratified-proportional sampling on the basis of high school enrollment. The sample as drawn contained 49 Kansas high schools enrolling 1,445 seniors. There were 716 males and 729 females in the total group.

The two studies are sufficient for our purposes. What then is an analytic survey? It is a survey characterized by these essentials: (1) representative sampling, and (2) quantitative data amenable to statistical treatment and subsequent statistical inference.

Analytic surveys, therefore, permit us to answer questions about a specific population. Barr, Davis, and Johnson characterize the essentials well in the following statement:

In the analytic problem the purpose of the sampling survey is to inquire into the underlying factors or causes that may have given rise to an observed condition or situation.

If sample surveys are to provide the basis for decision and action, the sample results must be capable of translation and interpretation in such a way that may provide maximum information. The conclusions are drawn for the population. They are inferred from the information available in the sample results. To provide this basis for decision and action, the sample must be a probability sample.

The theory of probability cannot be applied to a sample that is not randomly taken. Hence it is not possible to measure the degree of confidence to be placed in any inference drawn from a non-random sample. In addition to the random process of selection, the biases of selection, nonresponse, and estimation must be in effect eliminated or contained within known limits. This is necessary if sample errors are to be calculated and if probability statements involved in testing statistical hypotheses and in estimating population values are to have meaning.[17]

Thus it may be said that analytic surveys, as contrasted to normative surveys, afford a sounder basis for decision making and action, because the conditions imposed on the method of inquiry are more rigorous in the sense that they permit the drawing of statistical inferences to a larger specified population.

It is not necessary in an analytic survey to limit the statistical analyses of the data obtained from a representative sample to single factor comparisons. In fact, if one applies the "Golden Rule" of statistics and thus gives consideration to the statistical techniques to be used in subsequent analyses, he may on the basis of his representative sample, plan a design which allows all the essential conditions to vary simultaneously rather than one at a time. The results, therefore, will have wider applicability.

Two such studies[18] published in *Science Education* in April 1961 make use of "multivariate analysis" in the form of a factorial design imploying analysis of

[15] *Essential High School Content Battery*. World Book Company, Yonkers-on-Hudson, New York, 1951.

[16] *Terman-McNemar Test of Mental Ability, Form C*. World Book Company, Yonkers-on-Hudson, New York, 1941.

[17] Arvil S. Barr, Robert A. Davis, and Palmer O. Johnson, *op. cit.*, p. 187.

[18] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Sex as the Main Variables," and "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Career Plans as the Main Variables," *Science Education*, 45 (April, 1961), 269–274; 275–278.

covariance in the statistical analysis. In these studies, the sample of schools chosen were not representative of the schools of Kansas but consisted of the five large high schools in Wichita, Kansas. However, if the chemistry classes in these schools are considered as the sample, and if the students had been assigned to film and non-film classes by random means, then the scores of the forty students selected at random from the four sub-populations would constitute a representative sample. The survey evidence, therefore, secured from the statistical analyses, would have provided a valid basis for generalizations about all of the chemistry students in Wichita in terms of the variables under consideration.

Actually, ten students were selected by means of random numbers from four sub-populations as follows:

1. First Study:

Film Method—Male	79
Film Method—Female	49
Non-Film Method—Male	289
Non-Film Method—Female	173

2. Second Study:

Film Method—Science Career	65
Film Method—Non-Science Career	62
Non-Film Method—Science Career	190
Non-Film Method—Non-Science Career	373

The ten scores in each study were placed in one of the cells of a 2 x 2 table as follows:

1. First Study:

Group	Male	Female
Film		
Non-Film		

2. Second Study:

Group	Science Career	Non-Science Career
Film		
Non-Film		

The statistical technique used was that of analysis of covariance in which raw scores on the pre-test (*Anderson Chemistry Test,* World Book Company) and raw SCAT scores (*School and College Ability Tests,* Educational Testing Service) were controlled.

The results of the analysis yielded the following conclusions:

1. First Study:

   The non-film group achieved significantly more than the film group with pre-test and SCAT scores held constant. Since the F values for sex and interaction were not significant, the conclusion was not biased by the factor of sex nor influenced by an interaction between sex and method.

2. Second Study:

   The film and non-film groups achieved the same with pre-test and SCAT scores held constant. The science career students achieved significantly more than the non-science career students with pre-test and SCAT scores held constant, since the F was significant at the 5 per cent level and the adjusted means were 53.35 and 45.95 respectively. Since the F values for method and interaction were not significant, the conclusion was not biased by the factor of method nor influenced by interaction between method and career. Since the F value for career was significant, control of this factor by stratification was justified.

Thus, in conclusion, it may be seen that the limits of the analytic survey may be extended to more advanced designs in which several main variables may be involved. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results, therefore, have wider applicability than do single-factor comparisons since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.

AVENUES FOR THE IMPROVEMENT OF RESEARCH *

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In a population which is so dependent on research, it is sad to reflect how few people perceive what it is all about. Research is an approach to a comprehension of the universe along a broad thoroughfare of organized knowledge solidly established on observation and experiment imbedded in a matrix of theory. It is a highway that is continuously being lengthened, widened, and mended.[1]

Whether or not we agree with Johnson's definition of research, his definition contains the essentials upon which good research must be based: (1) organized knowledge, (2) observation and experiment, and (3) theory. These three essentials constitute a void or a formidable roadblock preventing the free flow of good research. All three are generally necessary to the production of good research; no one of the three is sufficient in itself. How a particular academic area or discipline views these three essentials is dependent to some extent on the nature of that discipline—its breadth of coverage and level of theory development, and how it views observation and experimentation.

In education and in science education, it is a most difficult task to achieve a blending of these essentials in the proper proportions since the area of endeavor is a complex of many things. Its level of theory development is low and its breadth of coverage is extremely wide. These in combination have lead to an "arm-chair" approach to the problems of education by many self-appointed experts in and outside the field whose repertoire is lacking in one or more or all of these three essentials. Experts, otherwise well equipped, have avoided observation and experimentation as a source of truth due to the remarkable breadth and complexity of educational measurement.

In science education it is imperative that the researcher have a sound grasp of the organized knowledge in some scientific area such as physics or chemistry in which he proposes to research. He should have more than a nodding acquaintance with philosophy of science as represented by such men as Herbert Feigl, Morris R. Cohen, Ernest Nagel, and P. W. Bridgman.[2] These in combination will add to the rigorousness of the researcher's work in terms of the method of science and afford a theoretical basis for his exploration of pertinent problems.

The above might be sufficient for the researcher in science, but there is another dimension which is crucial to the science educator in which the three essential conditions must be repeated if he is to conduct good research. This is the complex of education involving pertinent applications from the organized areas of knowledge such as economics, sociology, psychology, and statistics. A fair grasp of these disciplines coupled with a sophisticated understanding of educational philosophy, learning theory,[3] educational measurement,[4] and techniques

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[1] Palmer O. Johnson, "Introductory Remarks at Opening of the Symposium on Educational Research," *First Annual Phi Delta Kappa Symposium on Educational Research*, Phi Delta Kappa, Inc., Bloomington, Indiana, 1960, p. XV.

[2] Herbert Feigl and May Broadbeck, *Readings in the Philosophy of Science.* Appleton-Century-Crofts, Inc., New York, 1953, 811 pp.

[3] Ernest R. Hilgard, *Theories of Learning*, Appleton-Century-Crofts, Inc., New York, 1956, 563 pp.

[4] E. F. Lindquist, *Educational Measurement*, American Council on Education, Washington, D. C., 1951, 819 pp.

of educational research [5] are essential to the production of good research in education. Research is also needed in educational measurement since educational research has been handicapped by inadequate methods of measurement and the absence of feasible methods of measurement may block off entire areas from significant inquiry. Adequate methods of measurement are as essential to progress in education as they have been for progress in the scientific disciplines. Thus, the road to good research in science education is a complicated highway and the equipment must be good if one is to reach the end of the road and deliver his cargo of usable goods intact.

What constitutes good research in the field of education? Good studies are essential if research is to be implemented in action in the educational process. Nicholas A. Fattu [6] discusses the characteristics of good studies in some detail and I quote as follows:

A good study puts us ahead of where we are now, tackles problems not handled by peers, solves problems that others have failed to solve. A good study makes a difference in educational practice if the potential applications are taken seriously. A good study is imaginative, ingenious, and productive of new approaches, new ideas, and new data. A good study fits into a pattern of long range work. It has antecedents and consequents, and the total result is increased understanding of a field as a result of the accumulation of studies.

A good study is carefully designed and planned. It identifies a definite problem. All parts of the procedure are relevant to the question being studied—data collected, analysis of data. The interpretation of findings or meanings of results is directly related to the organization of the study and the procedures used. The results are also directly related to the conceptualization used, and may suggest new data and new concepts.

A good study is aimed at discovering truth, not at supporting a current or proposed practice. It deals with more general and universal aspects of questions that concern education. The goal is not to find a quick solution but to develop tested principles. Results of a good study can be communicated to peers working in the same area.

A good study is appropriate to the level of development of its field and to the questions asked. Education is an enormous public enterprise engaged in a form of mass production. It is impossible to operate on this scale without systematic quality control, for without quality control we don't know where we stand, and we cannot correct the weak spots. A program of quality control involves systematic and continuous collection of facts on pupils, including long term follow-up of graduates. Data would include tests but would also include data on motivation, socio-economic background, level of aspiration, emotionality, etc. Operations research tells the school about its raw material and about its output. Operations research and quality control methods could be applied to operational data.

In a previous paper entitled "Implementing Research Into Action," [7] the writer emphasized that:

School personnel must be made a real working part of the research team and acquire some psychological ownership of the research process if research is to be implemented into action.

Psychological ownership cannot be acquired in full by active participation in the research process. Prior to or along with participation must be some solid exposure to: (1) formal instruction in the discipline or in the area where the educational research is to be conducted; (2) psychology of learning, both in the psychology of learning per se and in psychology of learning as applied to a particular academic area; and (3) methods of educational research and the applications of statistical methods to research in education.

The first of these points need not be labored upon too long. It should be obvious even to the "starry-eyed educator," that one cannot do much real educational research unless he knows his academic field well. The researcher must be well-grounded in his discipline at the undergraduate level and in addition have pursued some real graduate work in the area. Programs in teacher education must demand real academic attainment in the major or minor teaching field.

The second of the points listed above need not be treated at length in this discussion. Pertinent to the discussion, however, is the following statement:

"Education is an integral part of modern life. Modern individual and social life encompasses a great complexity of phenomena. Systematic and orderly investigations of the "great buzzing confusion" of life require conceptualizations, that is,

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[5] Arvid S. Barr, Robert A. Davis, and Palmer O. Johnson, *Educational Research and Appraisal*, J. B. Lippincott Company, Chicago, 1953, 362 pp.

[6] Nicholas A. Fattu, "A Survey of Educational Research at Selected Universities," *First Annual Phi Delta Kappa Symposium on Educational Research*, Phi Delta Kappa, Inc., Bloomington, Indiana, 1960, p. 15.

[7] Kenneth E. Anderson, "Implementing Research into Action," *Science Education*, 44 (April, 1960), 178–187.

views of what to look for, how to look for them, and what kinds of structures, processes, and relationships are involved. If when one entered a classroom he had no prior conceptualization of teaching and learning, he would see children and an adult, he would hear several children and the adult speaking, he would note physical items in the room, movements of people, and the like. What gives it meaning for the investigator of classroom instruction is a "model" which he conceives, a simplified picture of the structure and process of classroom instruction. This model usually includes such elements as a teacher, pupils, objectives of instruction, learning outcomes. If he holds such a model in mind, he has a basis for focusing his observations and for arranging and analyzing his data. This development of a formal model provides a way of viewing the complex phenomena in a fashion which permits scientific study. Models serve to simplify a process which appears on the surface to be too varied or complex or haphazard to be understood. But models must not only simplify complex phenomena but they must provide a means for explaining and predicting the variations and regularities observed in the phenomena. Hence, conceptualizations change as research indicates that earlier models fail to explain or predict many of the observations noted. For example, a common model for research in instruction in the 1920's included a teacher, a group of pupils, methods of teaching, learning outcomes.

"This conceptualization recognized variations in the intelligence of pupils, various methods of teaching and variations in the degree of achievement by the pupils of the learning outcomes. Since that time, a number of things have been added to this model, such as variations in the skills, preparation, and personalities of teachers, variations in the initial achievement of pupils, in the kinds of pupil motivation, in the content and intensity of pupil interests, and variations among several major kinds of educational outcomes, such as knowledge, skills, attitudes, and problem-solving. Effective educational research is commonly guided by conceptualizations which provide ways of viewing the complexity of educational phenomena in orderly and meaningful patterns." [8]

The third point listed at the beginning of the last quotation is particularly important for it is in this area that the real break-through in educational research may occur. I quote:

As is so often the case, a study of a particular problem in education is given a stamp of approval or is labeled respectable, because the study contains a number of tables which are statistical in nature. Actually, statistical analysis of data is only in order providing the researcher:

1. Selects the appropriate statistical technique for the dåta at hand and in addition tests the assumptions basic to the technique. This implies an adequate background in the field of statistics and measurement. Even the coroner conducting a post-mortem examination selects appropriate tools and techniques, but even then his examination more often than not fails to produce additions to the knowledge of medicine.

2. Applies the "Golden Rule" of statistics. This in essence means that consideration is given to statistical techniques early in the study, which is often a controlled experiment, before the data have been gathered. Too many studies supposedly experimental in nature are like corpses —all that one can do is hold a post-mortem examination. An experimental study should be carefully planned in advance under conditions which will afford a secure basis for new additions to knowledge.

In most investigations other than the descriptive type, the two chief problems are: (1) testing statistical hypotheses, and (2) estimating population parameters. The first involves an exact test of significance or a test which is based on a known probability distribution. Usually this involves setting up the hypothesis as a null hypothesis, applying the appropriate statistical tool, referring the final result to the appropriate model or distribution, and last of all a rejection of the null hypothesis or its acceptance (failure to reject it).

It is essential in an experiment that the principle of randomization be observed. Otherwise a test of significance has no validity. It is important that groups of students which are to be treated differently, have the same probability of being so treated. In other words, the educational treatments should be randomized. In addition, the students should be assigned at random to the various groups receiving different educational treatments. Only when samples are obtained in this manner and only when the experiment makes it possible to secure a valid estimate of the experimental errors, is statistical inference permitted.

It is important in setting forth the plans of an experiment to answer the questions which prompted the research and to list all the variables that might conceivably influence the results. In an experiment based on the assumption of controlling all factors except the one under investigation, it is often observed that results will change from one experiment to another of the same kind. If all the essential conditions are varied simultaneously rather than one at a time, one can observe the effects of the factors in a nearly natural setting. Factorial design is appropriate because the effects of the interactions of all combinations of factors under consideration are measured. . . . The chief advantages of factorial experiments are: (1) greater efficiency, and (2)

[8] Ralph W. Tyler, "The Contribution of the Behavioral Sciences to Educational Research," *First Annual Phi Delta Kappa Symposium on Educational Research*, Phi Delta Kappa, Inc., Bloomington, Indiana, pp. 57–58.

greater comprehensiveness in that effects and interactions are estimated, and (3) that the conclusions have a wider inductive basis.

It is possible to partial out in a factorial design, such as the above, the effects of pre-science information and intelligence. This would call for a factorial design involving analysis of covariance.

Consideration of designs of the factorial type before the investigation gets underway might make the research efforts more fruitful.

. . . the research worker in science education should: (1) use adequate and reliable statistics when the research calls for description, (2) use statistical techniques properly by testing assumptions basic to the techniques, and (3) select and use statistical tools in the early stages of an investigation. In addition, the research worker in science education should be aware of new statistical tools and sampling distributions available for exact tests of significance and think of problems in science education not only in terms of tests of significance but in terms of problems of estimation.

Finally, the science researcher should use the powerful tool of analysis of variance and covariance to bolster the controlled experiment in science education, and insofar as possible consider in future studies the possibilities of varying all the essential conditions simultaneously by designs of the factorial type so that our findings will reflect natural settings and thus have wider applicability in our science teaching. When this becomes an accomplished fact, science teaching via realistic research will improve immensely.[9]

When the above quotation was written in 1954, some reference to multivariate analysis was appearing in the literature. Today, there is not an abundance of space devoted to the topic, but many scholars in the area believe that multivariate analysis may trigger a real breakthrough in educational research. To quote Johnson and Jackson, we may say:

> As a general rule, in fact, any phenomenon under observation is, or may be, affected by the influence of numerous factors, and these factors may be related among themselves—sometimes operating in the same direction, sometimes in opposition. One of the tasks of the researcher is to identify and describe these relationships and inter-relationships.[10]

[9] Kenneth E. Anderson, "The Statistical Approach to Problems in Science Education," *Science Education*, 38 (December, 1954), 390–397.

[10] Palmer O. Johnson and Robert W. B. Jackson, *Modern Statistical Methods: Descriptive and Inductive*, Rand McNally and Company, Chicago, 1959, p. 371.

Multivariate analysis is a mode of statistical operation and may involve such methods as: partial and multiple regression and correlation, factorial design involving analysis of covariance, and the discriminant function. Illustrative of a very simple application of the method of multivariate analysis is a study by Anderson and others.[11]

In this study the problem was one of testing which method produced superior results in measured achievement during one year of instruction: the conventional method or the film method of instruction. The design of the study was a 2 x 2 factorial type. The factors were the two sexes (male and female) and the two methods (film or non-film) of instruction. Analysis of covariance was introduced in that the pre-test and SCAT scores were held constant. The factorial design employed permitted stratification of the data and the testing of three null hypotheses as follows:

1. Students taught by the film method did not differ in achievement in high school chemistry from the students taught by the non-film method with pre-test and SCAT scores held constant.

2. Male students did not differ in achievement in high school chemistry from the female students with pre-test and SCAT scores held constant.

3. The sexes did not differ in achievement in high school chemistry when taught by the film method and when taught by the non-film method with pre-test and SCAT scores held constant.

The primary hypothesis was the first and hypotheses two and three help make the first more meaningful than had they not been introduced into the problem.

[11] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, "An Analysis of the Introductory Chemistry Course on Films by Factorial Design and Covariance with Method and Sex as the Main Variables," *Science Education*, 45 (April, 1961), 269–274.

From the standpoint of the efficiency of the factorial design, it can be said that we have tested one hypothesis regarding interaction and two hypotheses concerning main effects. If the single-factor plan of experiment had been used, the two main hypotheses would have required separate treatments and no information would have been possible concerning the effect of interaction. The following four groups could have been compared at once in one analysis of covariance: (1) film-male, (2) film-female, (3) non-film-male, and (4) non-film-female. However, six t tests would have been subsequently required, and again the interaction effect would not have been available.

In this study, ten students were selected by means of random numbers from each of the following groups:

Film Method—Male	79
Film Method—Female	49
Non-Film Method—Male	289
Non-Film Method—Female	173

The sums of scores, sums of scores squared, and sums of cross products were obtained for the three measures X, Y, and Z. From these, the sums of squares or SS's (Σx^2, Σy^2, Σz^2, Σxz, Σxy, Σyz) were obtained for: (1) the total sample, (2) method, (2) sex, (4) interaction, (5) within, (6) method plus within, (7) sex plus within, and (8) interaction plus within. The following regression cofficients were used in obtaining the SS's:

$$b_1 = \frac{(\Sigma xz)(\Sigma y^2) - (\Sigma yz)(\Sigma xy)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

$$b_2 = \frac{(\Sigma x^2)(\Sigma yz) - (\Sigma xy)(\Sigma xz)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

The adjusted SS's were obtained by using the following formula:

$$SS = (\Sigma z^2 - b_1\Sigma xz - b_2\Sigma yz) - (\text{Adjusted SS for within})$$

The final step in analysis of covariance appears in the following table:

ANALYSIS OF COVARIANCE

Source of Variation	df	Adjusted SS	MS	Probability
Method	1	555.50	9.58	P<.01
Sex	1	127.03	2.19	P>.05
Interaction	1	10.65	0.18	P>.05
Within	34	1,970.64	...	......
Total	37	2,623.53	...	......

Three scores for each student were placed in one of the cells of a 2 x 2 table as follows:

Group	Male			Female		
	X*	Y†	Z‡	X*	Y†	Z‡
Film						
Non-Film						

The significance of the mean squares was determined by entering the F table with 1 and 34 degrees of freedom. The mean square for method was the only significant one and indicates that a significant difference in chemistry achievement oc-

* Raw scores on the pre-test (*Anderson Chemistry Test*, Form Am, World Book Company, Yonkers-on-Hudson, New York).

† Raw scores on the SCAT (*School and College Ability Tests*, Cooperative Test Division, Educational Testing Service, Princeton, New Jersey).

‡ Raw scores on the post-test (*Anderson Chemistry Test*, Form Am).

curred with pre-test and SCAT scores held constant in favor of the non-film group. The adjusted means were 48.49 and 41.06 respectively. Since the F value for sex was not significant, no bias was introduced by this factor. Also, since the F value for interaction was not significant, the difference in achievement of the students in the film and non-film methods cannot be accounted for on the basis of being a male or a female when taught by the film method and when taught by the non-film method.

Factors other than sex can be introduced into additional factorial designs. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results, therefore, have wider applicability than do single experiments, since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.

A similar study[12] was made using a 2 x 2 design involving the same types of scores for each student and where the main factors were method and career plans.

The problem was one of testing which method produced superior results in measured achievement during one year of instruction: the conventional method or the film method of instruction. The design of the study was a 2 x 2 factorial type. The factors were the two methods (film or non-film) of instruction and plans to go to college for a *science career and non-science career*. Analysis of covariance was introduced in that the pre-test and SCAT scores were held constant. The factorial design employed permitted stratification of the data and the testing of three null hypotheses as follows:

[12] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Career Plans as the Main Variables," *Science Education*, 45 (April, 1961), 275–278.

1. Students taught by the film method did not differ in achievement in high school chemistry from the students taught by the non-film method with pre-test and SCAT scores held constant.

2. Students who planned to go to college for a science career did not differ in achievement in high school chemistry from students who planned to go to college for a non-science career with pre-test and SCAT scores held constant.

3. The science career students did not differ in achievement in high school chemistry when taught by the film method and when taught by the non-film method from the non-science career students when taught in the same two ways.

The following conclusions were made on the basis of the data obtained:

1. The film and non-film groups achieved the same with pre-test and SCAT scores held constant. This was our primary hypothesis.

2. The science career students achieved significantly more than the non-science career students with pre-test and SCAT scores held constant, since the F was significant at the 5 per cent level and the adjusted means were 53.35 and 45.95 respectively. Since the F values for method and interaction were not significant, the conclusion was not biased by the factor of method nor influenced by interaction between method and career. Since the F value for career was significant, control of this factor by stratification was justified.

In summary, the "avenues for the improvement of research" is the preparation of research workers in science education who: (1) are well grounded in their academic fields, (2) know the academic areas related to and important to education, (3) know the psychology of learning, and (4) are sophisticated in the application of research and statistical methods to problems in educational fields.

In addition to these demanding requi-

sites, time and effort must be made to improve educational measurement and multivariate analysis must be employed with increasing frequency. The two in combination may well represent a crucial approach to problems in education, and if well done may constitute the break-through so desperately needed in educational research. *Die Wahrheit liegt in der Bewährung.* Truth is what stands the test of experience.

IMPROVING THE COMPETENCE OF TEACHERS IN MEASUREMENT AND EVALUATION *

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ONE of the most crucial problems facing American scientists today is the "Measurement Pinch" emphasized by the missile gap between Russia and the United States. The space age will belong to that country which first masters the basic problem of how to measure extremely small amounts (a millionth of an inch) of something or extremely large amounts (15,000° C.) of something. Failure to do this results in small errors which become greatly magnified when the goal is to hit the moon. Our scientists are hard at work on the problem of improving our measurement procedures, and the evidence would seem to indicate that we lag behind the Russians in this basic ingredient.[1]

Science today is so advanced that only a handful of men and women probably appreciate the crucial role measurement has played and will play in the science-technology race. However, this need not dismay us in Education, for we too have our problems in measurement even though the degree of precision needed is gross compared to that needed in the sciences. Let us therefore review briefly the development of measurement in science in understandable terms and draw from this development the essentials applicable to Education.

Ordinarily we associate measurement with science or related fields of knowledge. Measurement in science in the beginning was very crude. Man judged time by the period it required for a specific quantity of sand to flow from one vessel into another. Amounts of energy were judged in comparison with the amount of work performed by a horse in a specified period of time. Thus, we can see that the methods of measurement possessed various degrees of error and were not accurate.

For measurement to be really useful to man, it was necessary that accuracy be increased and that error be reduced to a minimum. Science is constantly devising more accurate methods of measurement based insofar as possible upon established standards.

What then is measurement? Is it a quantitative description of observed data? Yes, but more than that it is a means to an end, and exists for the sole purpose of discovering the numerical relationships which exist between the physical properties, as in science, or between the observed and recorded observations on animal characteristics and performance, as in psychology and education.

The roots of measurement may be found in the long established basic sciences. During the period from Galileo through the nineteenth century, the foundations were laid for the quantitative conquest of nature. We have learned that the events of nature are due to the mechanical forces of nature,

* Address given at the St. Louis Meeting of the American Association of School Administrators, March 14, 1961.

[1] Beverley Smith, Jr., "The Measurement Pinch," *The Saturday Evening Post*, September 10, 1960.

subject to law and order, and subject to measurement and mathematical treatment.

Without measurement as we know it today, science would still be groping in the real of half-truths as it did in the medieval days. Science in the middle ages was Aristotelian in nature, consisting largely of enumeration and classification. Enumeration is dependent on numbers as is measurement. Enumeration requires that we classify objects, but not as to length, color, or density. The objects must be nearly alike so that we might call then all balls. We may have handballs, basketballs, and baseballs, all of different diameters, but they would all be balls as far as classification is concerned. When we enumerate them we may count fifty balls. Enumeration, therefore, does not consider the variation of the balls in diameter or surface area, but simply answers the question *how many*.

In measurement we are interested in how much more or how much less of a certain property of matter. It was thus that science had to turn from the qualitative aspects to the quantitative aspects. We became interested not in the fact that iron expands when heated, but how much it expands with a certain temperature increase. Modern science, therefore, attempts to reduce phenomena into their elements and to describe these elements in a quantitative manner.

In enumeration or counting, there is a limitation that only discrete groups may be counted, or that there must be separate objects, as balls. They must all be balls or possess a constant character, that is to be classifiable into a group. Whether a scientist counts the balls or an untrained student, the results will be largely the same. The order of counting matters not at all, for again the results will be the same. In actual measurement we are not dealing with a discrete series but with a continuous increase or decrease of a property, or with different amounts of a continuous property as weight. The hardness scale of ten tells us that:

> Diamond is harder than steel, steel is harder than talc, and therefore, diamond is harder than talc.

We are not able to say that diamond is twice as hard as talc. Hardness, temperature, density, and intelligence are nonadditive. Measurement in a strict sense can take place only if the property is capable of being arranged in a series as is the case with the scale of hardness, and if the minimum requirements of addition are met. Thus we find that length, time, area, angles, electric current—are all capable of meeting the necessary conditions. They are fundamental units capable of addition. Measurement as indicated above answers the question *how much*.

In measurement we must manipulate a physical instrument, and record our readings as we do from a meter stick in measuring length. When we use a resistance box or a Wheatstone bridge we are no longer dealing with property, but with its effect. We make our evaluation by means of the instrument. Instruments aid man in detecting and describing, and the more instruments of this type we can devise, the more exact our knowledge will be. An instrument must be valid and reliable. Thus if we are measuring current, we should not use a resistance box, for this is not a valid use of the box. The instrument is not measuring what it purports to measure. An ammeter is designed to measure current, and if it does so consistently, it is a reliable instrument.

Instruments are of two classes. The first class such as the telescope, increases the power of our senses. Meter sticks and voltmeters are examples of the second class, for they enable us to give more exact quantitative descriptions of properties. In measurement we are more concerned with the latter type.

There must be several broad understandings behind the use of an instrument

that measures a particular property. Thus the ammeter, which measures the amount of current flowing in a wire, must have a shunt and be placed in series with the circuit. The laws of magnetism; the production of line of force about a wire carrying an electric current; the definition of an ampere as that amount of current that will deposit so much silver in one second; the calibration of the ammeter against this standard or definition—all these concepts lie behind the proper use of the instrument.

Thus, the antecedents of modern educational measurement are found in the sciences and in mathematics. Educational measurement has had many obstacles to overcome, because human abilities are difficult to define and therefore difficult to measure without considerable error. As one works in the area of educational measurement, he will see that educators too, are striving to develop more accurate ways of describing and quantifying human abilities and characteristics.

The measurement of human ability, such as the capacity to learn, requires that the property under consideration be one that can be: (1) clearly defined in unambiguous terms, (2) described as more or less in amount, (3) sampled, and (4) transformed into units which are constant and clear-cut in meaning.

Units are of two kinds: fundamental and derived. Length, time and weight are considered by the scientist to be fundamental units. The size of the unit is purely arbitrary. For example, the meter is the distance between two scratches on a bar made of platinum and iridium. Derived units are established with reference to fundamental units or by definition as is so often the case in psychology and education.

The question of "how much" or absolute measurement implies that absolute zero has been established and that the minimum requirements of addition have been met. Unfortunately, most of educational measurement is unable to meet the requirements of absolute measurement. Most of educational measurement is relative in that absolute zero cannot be established. We are unable to say that John has twice as much intelligence as Mary has, but merely that John has more intelligence than Mary has.

Objective measurement has serious limitations, in that the instrument does not always measure what it purports to measure and in addition it may not be dependable. The limitations of measurement have been partially described in the discussion of attributes of a measurable property. There are other limitations, however, which may be summarized under the *concept of error*. Error in measurement can probably never be eliminated and therefore we must accept it as a normal phenomenon. However, we must always, insofar as possible, minimize the errors of measurement by:

1. Perfecting our instruments.
2. Employing our instruments correctly.
3. Making statistical allowances for errors.

All three methods of reducing errors in measurement are important in descriptive statistics but the last method is given more attention when we are concerned with problems of estimation and tests of significance.

Lest we become indoctrinated with the belief that all appraisal of human abilities is quantitative in nature, let us hasten to add that psychologists and educators in appraising human abilities employ other instruments such as: observation, rating scales, questionnaires, case studies, and individual performance. One must be further reminded that measurement and evaluation are preceded by the contributions of the philosopher and the curriculum maker.

Educational evaluation is a recurring process that involves the formulating of objectives of instruction consistent with an over-all philosophy, defining the objectives of instruction, and measuring the learner's progress toward these objectives. The

process of evaluation may involve the use of statistical methods in the treatment of test data but only as a means to an end. The employment of statistical methods in the process of evaluation is appropriate only if the data warrant such treatment and the investigator planned for the application of such techniques in the early stages of the investigation. This process of evaluation often produces new objectives or an improvement of the old, better methods of instruction, new techniques of evaluation, and a modification of the total program of evaluation.

In other words, measurement and evaluation follow the establishment of objectives of instruction. Test construction, treatment of test data, and other methods of educational appraisal cannot proceed until there is something to measure.

Evaluation then must involve objectives and an appraisal of whether or not these objectives have been reached. What are some important objectives or criteria of learning? These may be stated in many ways but are not the following almost all-inclusive?

Has the learner:

1. acquired and retained useful and pertinent information of a factual nature?
2. acquired and retained a workable understanding of the principles or *big ideas* of an academic field?
3. learned to use intelligent methods in adapting to the problems of his life?
4. reached a level of understanding, application, and performance in the above three which is commensurate with his ability?

The purpose of this discussion was to point out that:

> . . . evaluation must be geared to objectives along a continuum from simple understandings and skills and limited adaptability to more complete understandings and complex skills and greater adaptability. Where we as students and teachers are on this continuum determines the evaluation procedures to be employed. As long as we operate on a rather low level of understanding near the lower end of the continuum, the ordinary evaluation procedures will suffice. A little thought and ingenuity, however, can lift us off the lower levels of evaluation and place us a bit higher on the continuum. As we and our students continue to move upward in an understanding of what we are trying to accomplish, the simpler procedures will no longer evaluate adequately the transfer of understandings and abilities of the pupils.[2]

To move ourselves as teachers up higher on the evaluation continuum, we need to:

1. Keep anecdotal records or secure evidence of the degree to which our instruction and guidance operates in the lives of boys and girls.
2. Devise written tests describing real life situations which will afford us opportunities to appraise the pupil's understanding of himself and others and the world around him.
3. Provide opportunities for evaluating students in action on real problems of concern to themselves and society rather than having them repeat the errors of their forefathers.

We know that all teachers are aware of the great variation in the abilities of pupils in their classes. Few teachers, however, realize fully the extent of these differences and have available the necessary information to describe them objectively. An adequate testing program is the necessary first step in knowing what some of the differences are and in setting up a program to provide for them.

A comprehensive battery of achievement tests administered each year during the same month of the school year will go far: (1) in providing the staff with some real understanding of the extent and nature of individual differences; and (2) in providing a certain psychological security to the faculty, pupils, and parents, by revealing evidence of growth on the part of pupils in the basic areas of learning. In this way the extent of the yearly development of each pupil in reading vocabulary, reading comprehension, arithmetic reasoning, arithmetic computation, study skills, and language skills can be determined. In addition, a yearly testing program will reveal that the spread of differences exist each

[2] Kenneth E. Anderson and Gordon M. A. Mork, "Evaluating Science Teaching," *Science for Today's Children*, Thirty-Second Yearbook, Department of Elementary School Principals, National Education Association, Volume 33 (September, 1953), p. 141.

year, but that the relative position of an individual in the group will not be static.

The test scores obtained by a comprehensive testing program should be graphically recorded and kept in a permanent folder available to teachers at all times. The intelligent use of profile sheets and overlay acetates enhance the values accruing from a standardized testing program.[3] Dr. Collister, Director of the University of Kansas Guidance Bureau, and I, have used these methods successfully in our consultant work in the United States Indian Services. Some 8,000 Indian children in grades four to twelve in the Southwest were tested and profiles drawn. Observation and confession have revealed that the teachers in the Southwest acquired psychological ownership of the concept of individual differences as they existed in their pupils.

The statistical maneuvers necessary to provide the profile sheets, overlay acetates, estimates of errors of measurements, and norms, important as they are, are far outweighed by the fact that the teachers of children will discover for themselves the range of abilities existing in the children they teach. For example, research studies have shown a range in reading ability in the seventh grade of about eight years. The ranges of abilities in the achievement fields, which depend largely on reading ability, were almost as great. Common as the research findings are, one still encounters teachers, administrators, and parents, who believe in grade levels as rather definite stages of development. The chances are, that knowing individual differences first hand, action will be taken resulting in the improvement of the individual child as well as the entire group.

In order for teachers to participate effectively in the evaluation process they must acquire an adequate degree of mastery with regard to the simple statistical measures and techniques as used in Education. To shy away from these because it involves some mathematics and an elementary understanding of the theory of probability, is to hide one's head in the sand and to continue to practice many of the unproved methods of instruction. If elementary school children can acquire an understanding of measurement, as has been demonstrated by Burns[4] in a Kansas school system, and if today's high school students can master elementary statistics as taught in the newer mathematics sequence, then surely teachers at all levels can master the concepts associated with the following: (1) measures of central tendency, (2) measures of variability, (3) correlation, (4) reliability, (5) validity, (6) error of measurement, (7) grading,[5] (8) true score, (9) standard scores, (10) percentile ranks, and (11) simple methods of comparing groups such as the critical ratio and t test.

The above seems to be a rather inclusive list, but it does point up the complex nature of evaluation as applied to schools in general and as it should be used by teachers in their work. The approximate nature of educational measurement and evaluation should awaken in conscientious teachers, a desire to develop and create more efficient tools and techniques for appraising pupil behavior and development. Until this is done and teachers acquire some psychological ownership of educational measurement, we will be handicapped by a growing "measurement pinch," as is now being experienced by our scientists and engineers.

[3] Victor H. Noll, *Introduction to Educational Measurement*, Houghton Mifflin Company, Boston, 1957, pp. 356–357.

[4] Paul C. Burns, "Understanding Measurement," *The University of Kansas Bulletin of Education*, 15 (November, 1960) 13–19.

[5] Dale P. Scannell, "Making Grades More Meaningful: A Proposal," *The University of Kansas Bulletin of Education*, 15 (November, 1960) 25–35.

Perhaps the breakthrough in education will come about when we in Education make an all-out commitment to the worth of the research process.

Perhaps the following is pertinent as a conclusion to my remarks:

Research can serve education in the same way that it serves such fields as medicine and agriculture. It can test the effectiveness of new programs; it can establish principles which will suggest new procedures. Changes are being proposed and made in our educational programs because of the current concern that all citizens shall achieve their full educational potentials. We would be delinquent in our duty if, at the same time, we did not strengthen and extend the program of evaluation whereby we might know whether the new programs are producing their intended results.

Research is needed today to resolve the heated, and often bitter, controversies regarding educational policies and methods. Many of these differences in views stem from a lack of basic knowledge regarding learning and learners. Only when we know what various educational programs produce, and when these results are attested by objective scientific evidence, can we settle upon the better programs.

It is not enough to urge classroom teachers to put more effort into teaching subjects by traditional methods. Many current methods are the product of years of traditional practice and they are not necessarily "the most effective" in terms of current needs and knowledge. Over a period of years research has shown repeatedly that traditional methods are often based in part upon false principles of learning and that new methods can be devised to replace them.

We need research not only on educational methods, but we need a great deal of research upon the problems of motivation; we need to know far more about aptitudes and their development; we need to know more about the social forces which encourage or discourage youth from staying in school or entering a learned profession. Research has already provided insights and techniques for making better use of our human resources, but we shall remain comparatively ineffective until we know far more than we do now.[6]

And finally, to return to the title of this paper, I quote from the Fifth Book of Moses, commonly called Deuteronomy, as follows: "A perfect and just measure shalt thou have: that thy days may be lengthened in the land which the Lord thy God giveth thee."

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[6] Kenneth E. Anderson, "A Report from the American Educational Research Association President," *AERA Newsletter,* 10 (October, 1959), p. 1 and 3.

AUDIO-VISUAL RESEARCH *

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Major efforts to influence the science and mathematics curricula by all levels of government, by professional societies, by institutions of higher learning, and by an impressive array of National committees are manifest on every hand. This changing educational climate has been brought about by a complex of factors including the threat to national survival, a maturing scientific and technological society, and a reluctant abandonment of a traditional national provincialism.

Although the changes in science and mathematics, both actual and proposed, are of major proportions, this fact has not produced any pronounced shifts in the nature or volume of the related educational research produced. In fact, one is impressed by the sparsity of the evidence adduced which would either affirm or deny the efficacy of many of the large experimental programs. There is obviously a need for a more thoroughgoing consideration of evaluative techniques and procedures and for the planning of comprehensive educational research efforts in connection with programs which involve vast sums of money and millions of children. Perhaps the next reviewers will be able to report more positively on developments in research which more adequately reflect the level of current activity in the fields of science and mathematics.[1]

The above quotation, which appeared in the June 1961 issue of the *Review of Educational Research,* reflects the current situation with regard to research in the fields of science and mathematics. Many of the studies to be reviewed in this coming issue were concerned with audio-visual research in the teaching of science and it will be the purpose of this paper to review only five of the studies which appeared or will appear in *Science Education* from 1956 to 1961. The sixth study was a research project supported by a grant from the United States Office of Education.

It is important at this point, however, to ask the question: Is not the central and underlying purpose of research in education the improvement of instruction? If this be the primary purpose, then the real problem is the evaluation of the outcomes of instruction via audio visual aids, teaching machines, and programmed learning. What are some important objectives or criteria of learning? These may be stated in many ways but are not the following almost all inclusive?

Has the learner:

1. acquired and retained useful and pertinent information of a factual nature?
2. acquired and retained a workable understanding of the principles or *big ideas* of an academic field?
3. learned to use intelligent methods in adapting to the problems of his life?
4. reached a level of understanding, application, and performance in the above three which is commensurate with his ability?

. . . . evaluation must be geared to objectives along a continuum from simple understandings and skills and limited adaptability to more complete understandings and complex skills and greater adaptability. Where we as students and teachers are on this continuum determines the evaluation procedures to be employed. As long as we operate on a rather low level of understanding near the lower end of the continuum, the ordinary evaluation procedures will suffice. A little thought and ingenuity, however, can left us off the lower levels of evaluation and place us a bit higher on the continuum. As we and our students continue to move upward in an understanding of what we are trying to accomplish, the simpler procedures

* Paper presented at The University of Kansas Conference on Programmed Learning, April 15, 1961, Lawrence, Kansas.

[1] Kenneth E. Anderson and Herbert A. Smith, Co-chairmen of the June 1961 issue of the *Review of Educational Research* entitled: "Natural Sciences and Mathematics."

will no longer evaluate adequately the transfer of understandings and abilities of the pupils.[2]

Regardless of whether or not you subscribe to the above criteria of learning in terms of a continuum or spectrum, it is imperative that the purposes of a research study be couched in terms of sound learning objectives if the research study is to have a chance of being implemented into action.

In the pamphlet entitled *Analysis of Research in the Teaching of Science,* published by the United States Office of Education, one study appropriate to the discussion of the conference was cited "for excellence in dealing with one or more (in some cases, all) of the following aspects of craftsmanship in educational research—choosing a significant problem, validating data, using statistical analysis, and reporting." [3] The study cited was entitled: "An Inquiry into Some Possible Learning Differentials as a Result of the Use of Sound Motion Pictures in High School Biology." [4] This study, however, was based on a previous study entitled: "Toward a More Effective Use of Sound Motion Pictures in High School Biology." [5]

The problem of this study is quoted verbatim from the article which appeared in the February 1956 issue of *Science Education.* It reads:

After identification of the principles covered or stressed in the twenty films, an experimental design was developed in which films and principles were introduced into an experimental situation in order to determine the effectiveness of films *in contributing to the understanding and application of principles of biological science when different teaching procedures were employed.*

Three groups were established as follows:

Group I. A control group in which no films were shown or in which the teachers showed some films of their own choice.

Group II. An experimental group in which students saw the films at intervals throughout the school year. Teachers in these classes made their own preparations for the showing of the films.

Group III. An experimental group which saw the films at intervals throughout the school year bolstered by the emphasizing of the principles *covered* or *stressed* in each film. The teachers of these classes received the following directions with each film:

"Enclosed are sheets listing thirty-four biological principles selected from W. Edgar Martin's list of 300 major principles of the biological sciences. You will note upon examination of the sheets that the numbers of certain biological principles are circled in black, and others in red. If the number of the principle is circled in black, that principle is covered in the film. If the number of the principle is circled in red, that principle is stressed in the film. It is important *before the showing of the film* that you point out the principles which will be covered in the film. Use the chalk board or other means to inform your students of the principles covered in the film. *After the showing of the film,* stress the biological principles in your teaching."

Thus, three groups of classes were involved as follows: Group I, the Control Group; Group II, the Film Group; and Group III, the Films-with-Principles-Stressed Group. Thus, the problem became one of testing which method produced superior results in measured achievement during the period of one school year of instruction. The design adopted required that differences which might occur in performance of the three groups were to be tested for significance by assumption of the null hypothesis.

One of the interesting analyses of the data in the above study may be summarized as follows:

An interesting area of speculation in the interpretation of an experimental study is suggested by Lucow who said: "It is here suggested as a postulate in educational philosophy that greater variation in classroom achievement is evidence of the release of individual differences among pupils during the learning process." Lucow went on to say: "A change in variance

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[2] Kenneth E. Anderson, "Implementing Research Into Action," *Science Education,* 44 (April, 1960), 178–187.

[3] *Analysis of Research in the Teaching of Science, July 1956–July 1957,* U. S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1960, No. 2, pp. 33–34.

[4] Herbert A. Smith and Kenneth E. Anderson, "An Inquiry into Some Possible Learning Differentials as a Result of the Use of Sound Motion Pictures in High School Biology," *Science Education,* 42 (February, 1958), 34–37.

[5] Kenneth E. Anderson, Fred S. Montgomery, Herbert A. Smith, and Dorothy S. Anderson, "Toward a More Effective Use of Sound Motion Pictures in High School Biology," *Science Education,* 40 (February, 1956), 43–54.

from pre-test to after-test was considered to be of greater import than the change in means, under the assumption that greater variance in a group indicated greater expression of individual differences."

Which of the three methods as used in this study produced the greatest change in variance from the pre-test to the post-test? In order to answer this question, it was necessary to establish a confidence interval for the ratio of post-test variance to pre-test variance for each of the three treatment methods.

The results of the above study were summarized as follows:

On the basis of the three techniques of statistical analysis used in this study, and within the limitations imposed by the tests employed, it may be concluded that:

1. No differences in achievement existed between the three treatment groups holding intelligence test scores and pre-test scores constant. This conclusion must be tempered by the fact that thirteen of the sixty groups could not be used in the analysis because of failure to meet one or more of the assumptions basic to the design of the investigation.

2. Differences in achievement existed between the treatment groups of the upper one-third in intelligence as measured and that these differences were in favor of the Group III or the Films-with-Principles-Stressed Group as contrasted to Groups II and I or the Film Group and the Control Group. The same conclusion applies for students in the lower one-third in intelligence as measured but the differences were not as marked.

3. Another index of the superiority of Method III to Methods II and I was found in the increase in variance from pre-test to post-test. Method II was superior to Method I in this same respect.

Thus, there is some evidence that the Films-with-Principles-Stressed Method yielded results somewhat superior to the Film Method, and that the Film Method yielded results somewhat superior to a conventional method as used in Control Group.

Another study appropriate to the discussion of the conference was one entitled: "An Evaluation of the Introductory Physics Course on Film."[6] The problem of this study was:

The problem was one of testing which method produced superior results in measured achievement during the period of one school year of instruction: the conventional method or the film method of instruction. The design adopted required that differences which might occur in performance of the two groups were to be tested for significance by assumption of the null hypothesis.

In order to secure necessary data as a basis for a statistical test of the null hypothesis, it was decided to administer three tests as follows:

1. The *Dunning Physics Test, Form Am,* World Book Company, as a pre-test at the beginning of the school year, 1958–59.
2. The *Dunning Physics Test, Form Bm,* World Book Company, as a post-test at the end of the school year, 1958–59.
3. The *Terman-McNemar Test of Mental Ability, Form C,* World Book Company, as an intelligence test during the middle of the school year, 1958–59.

The three hypotheses under test in the form of questions were as follows:

1. Did the experimental classes achieve significantly more than the control classes with intelligence quotients and pre-test scores held constant?

2. Did the students of the experimental classes with above average, average, and below average intelligence quotients achieve significantly more than their counterparts in the control classes?

3. Did the students in the experimental classes evidence a significantly greater change in variance from the pre- to the post-test than did the students in the control classes?

The results of the above study were summarized as follows:

The data presented in this study would lead one to conclude that the film method produced somewhat greater variability in achievement than did the conventional method. Therefore, in proportion as this is true, the film method was superior. Also, it seemed to produce greater variability than the conventional method for students in the I.Q. ranges 113–124 and 113 and below. Thus, one may conclude that the film method was superior to the conventional method for those groups of students.

The reactions of the teachers and the students would seem to indicate that there were too many films and that it would be a better procedure to select and show films once or twice a week. The films selected should be those for which equipment is not available and those that demonstrate principles and theories difficult to present in a typical high school classroom.

The conclusions of this study must be tempered by the fact that only the classes in two large selected schools were used. However, the use of two schools similar in size, purpose, and com-

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[6] Kenneth E. Anderson and Fred S. Montgomery, "An Evaluation of the Introductory Physics Course on Films," *Science Education,* 43 (December, 1959), 386–394.

munity background would tend to minimize the effect of these variables. No attempt was made to secure a random sample of physics classes in the State of Kansas since the cost of a set of films and distribution of the films to a large number of schools would have been difficult.

The results of this study parallel quite closely the results as obtained in the *Wisconsin Physics Film Evaluation Project* in which 30 control and 30 experimental schools were selected at random.

The same investigators completed three companion studies [7, 8, 9] involving a year-long study of the effectiveness of the Encyclopaedia Britannica Film Course on Chemistry. About 600 students of chemistry in the five Wichita high schools of Wichita, Kansas, were involved. A total of 33 chemistry classes participated in the study and nine teachers taught the 33 classes. Although three teachers taught both film and non-film classes, the mean number of semester hours of preparation in college science was 68 for the non-film teachers and 51 for the film teachers. The mean number of hours of preparation in college chemistry was 35 for the non-film teachers and 25 for the film teachers. The non-film teachers had on the average, 20 years of teaching experience as contrasted to seven years of teaching experience for the film teachers. Thus, as these factors influence achievement in chemistry, the balance was in favor of the non-film classes.

The thirty-three classes were composed of seven film classes and 26 non-film classes. In the case of the 26 non-film classes, the number was reduced to eight by combining the classes of each teacher. No statistical violence was done since an inspection of the means and variances for the criterion measures used in the study appeared to be relatively homogeneous. Thus the final composition of the groups used in the comparison were eight non-film groups and seven film groups.

The problem in the first study was one of testing which method produced superior results in measured achievement during the one school year of instruction: the conventional method or the film method of instruction. The design adopted required that differences which might occur in performance of the contrasting groups were to be tested for significance by assumption of the null hypothesis. Several specific null hypotheses were tested as follows:

1. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *Anderson Chemistry Test* with SCAT and Pre-Test Scores Held Constant?
2. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and Pre-Test Scores Held Constant?
3. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *Laboratory Techniques and Apparatus Test* with SCAT Scores Held Constant?
4. Six of the groups at one high school were given the *Anderson Chemistry Test* as a pre-test, mid-year test, and post-test. Were the gains from pre-test to mid-year test and from the mid-year to the post-test greater for the three film groups than for the three non-film groups?
5. Three teachers taught both film and non-film classes. Did the Film Classes Achieve Significantly More than the Non-Film Classes on:

A. The *Anderson Chemistry Test* with SCAT and Pre-Test Scores Held Constant?

B. The *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and Pre-test scores Held Constant?

C. The *Laboratory Techniques and Apparatus Test* with SCAT Scores Held Constant?

In order to secure necessary data for a statistical test of the null hypothesis, it was decided to administer four tests as follows:

1. The *Anderson Chemistry Test, Form Am,*[10] as a pre-test, mid-year test, and post-test at the end of the school year.
2. The *Laboratory Techniques and Apparatus*

[7] Kenneth E. Anderson, Fred S. Montgomery, Sid F. Moore, "An Evaluation of the Introductory Chemistry Course on Film," *Science Education,* 45 (April 1961), 254–269.

[8] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Sex as the Main Variables," *Science Education,* 45 (April 1961), 269–274.

[9] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Career Plans as the Main Variables," *Science Education,* 45 (April 1961), 275–278.

[10] Published by the World Book Company, Yonkers-on-Hudson, New York.

Test for High School Chemistry[11] as a post-test at the end of the school year.

3. The *A.C.S.-N.S.T.A. Cooperative Examination—High School Chemistry Form 1959* as a pre-test and post-test.[12] Part I was used as a pre-test and Part II was used as a post-test.

4. The SCAT or *School and College Ability Tests.*[13] Total score on this test was used in the calculations.

Raw scores obtained from these tests, were used in the statistical analysis which follow. All pre-tests were administered during the first two weeks of the school year and all post-tests were administered within the last two weeks of the school year. The SCAT and mid-year chemistry tests were administered at the mid-point of the school year.

Space does not permit a resume regarding each null hypothesis tested. However, the results may be summarized as follows:

The data presented in this study would seem to indicate that the students in the non-film classes achieved more in high school chemistry than did the students in the film classes. This statement is supported by the fact that in eight of the seventeen direct comparisons, the differences in measured achievement were significant and in favor of the non-film groups. Only three out of the seventeen differences were significant and in favor of the film groups. This was especially true for the *A.C.S.-N.S.T.A. Chemistry Examination* where five of the eight comparisons were significant and in favor of the non-film groups. The results were about equally divided in terms of the *Anderson Chemistry Test.* This may be due to the fact that the tests measured somewhat different abilities in chemistry. Two of the five comparisons for the *Laboratory Techniques and Apparatus Test* were significant and in favor of the non-film groups. Only one comparison was significant and in favor of the film groups.

When gains were compared on the *Anderson Chemistry Test* from the pre-test to the mid-year test and from the mid-year test to the post-test, there was some indication that the non-film groups were somewhat superior and that the film groups suffered a greater drop in achievement during the last half of the year than did the non-film groups. The students' reaction would seem to indicate that too many films were shown and that boredom had set in. This may account for the film groups greater drop in mean gain during the last half of the year.

[11] Published by Kenneth E. Anderson, Dean, School of Education, The University of Kansas, 1960.

[12] Published by the Examination Committee—A.C.S., St. Louis University.

[13] Published by the Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

When the film and non-film groups taught by the same teacher were compared, the results were in favor of the non-film groups. Four out of the nine comparisons were significant and in favor of the non-film groups. Only two of the nine comparisons were significant and in favor of the film groups.

The students in the film classes were asked to give their reaction to several questions and in general one might say that the students felt they would have done better in a conventional chemistry course. Evidently, the students in the film group missed the usual laboratory instruction since about 83 per cent would have liked more laboratory work. The students felt they might have done better had they used a textbook designed to accompany the films rather than using the textbook employed with the non-film groups.

The students thought the film instructor was excellent and that the colored film added a great deal. They also felt that the experiments shown in the films used excellent equipment not usually available in a high school laboratory. They felt that the use of this equipment and the fine execution of the experiments was something they would have missed in the conventional laboratory approach. They also liked the wide range of industrial applications of chemistry shown in the films. They felt that this was quite broadening and stimulated their interest in science.

The students felt there were too many films but almost an equal number would be willing to take another film course.

All in all, despite the better achievement of the non-film classes on the chemistry examinations used, one cannot say that the student's reaction was negative. In fact, they felt that they had gained much by being in the film classes.

Several of the students, and apparently the better students, felt that a better procedure would be a wise selection of the films by the teacher in terms of: (1) his preparation to teach chemistry, (2) the equipment and facilities available, and (3) the ability of his students to master the level of chemistry he is able to present.

The two companion studies published in *Science Education* in April made use of "multivariate analysis" in the form of a factorial design employing analysis of covariance in the statistical analysis.

In these studies, the sample of schools chosen were not representative of the schools of Kansas but consisted of the five large high schools in Wichita, Kansas. However, if the chemistry classes in these schools are considered as the sample, and if the students had been assigned to film and non-film classes by random means, then the scores of the forty students selected at random from the four sub-populations would constitute a representative sample. The survey evidence, therefore, secured from the statistical

analysis, would have provided a valid basis for generalizations about all of the chemistry students in Wichita in terms of the variables under consideration.

Actually, ten students were selected by means of random numbers from four sub-populations as follows:

1. First Study:

Film Method—Male	79
Film Method—Female	49
Non-Film Method—Male	289
Non-Film Method—Female	173

2. Second Study:

Film Method—Science Career	65
Film Method—Non-Science Career	62
Non-Film Method—Science Career	190
Non-Film Method—Non-Science Career	373

The ten scores in each study were placed in one of the cells of a 2 x 2 table as follows:

1. First Study:

Group	Male	Female
Film		
Non-Film		

2. Second Study:

Group	Science Career	Non-Science Career
Film		
Non-Film		

The statistical technique used was that of analysis of covariance in which raw scores on the pre-test (*Anderson Chemistry Test,* World Book Company) and raw SCAT scores (*School and College Ability Test,* Educational Testing Service) were controlled.

The results of the analyses yielded the following conclusions:

1. First Study:

   The non-film group achieved significantly more than the film group with pre-test and SCAT scores held constant. Since the F values for sex and interaction were not significant, the conclusion was not biased by the factor of sex nor influenced by an interaction between sex and method.

2. Second Study:

   The film and non-film groups achieved the same with pre-test and SCAT scores held constant. The science career students achieved significantly more than the non-science career students with pre-test and SCAT scores held constant, since the F was significant at the 5 per cent level and the adjusted means were 53.35 and 45.95 respectively. Since the F values for method and interaction were not significant, the conclusions was not biased by the factor of method nor influenced by interaction between method and career. Since the F value for career was significant, control of this factor by stratification was justified.

Thus, in conclusion, it may be seen that the limits of the analytic survey may be extended to more advanced designs in which several main variables may be involved. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results, therefore, have wider applicability than do single-factor comparsions since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.[14]

An excellent study by Popham and Sadnavitch entitled "An Analysis of Filmed Science Courses in Public Secondary Schools," concludes:

> The results of this investigation seem to raise doubts concerning the value of the filmed science courses, at least as they were employed in this experiment. This was particularly true in the case of the physics series. Of course, the many limitations associated with a single research project such as the one described herein do not permit one to draw definitive conclusions. However, research findings such as these should make it incumbent upon proponents of the filmed science courses to supply empirical evidence that the filmed technique produces educational gains which are at least comparable to those yielded by ordinary instructional methods. With a view to sound fiscal policies in the secondary school, the considerable cost associated with the purchase of the filmed science courses should dictate that more evidence supporting their effectiveness must be presented before a favorable judgment regarding the educational usefulness of the films can be reached.[15]

Thus the results of these six studies, although essentially negative, raise some interesting speculations. In the first study entitled "Toward a More Effective Use of Sound Motion Pictures in High School Biology," the teachers and students were made aware of the principles of biological science covered or stressed in each film. The focus of the instruction was on the principles and the teaching, therefore, was purposeful. The results, discounting any

[14] Kenneth E. Anderson, "Analytic Surveys," *Science Education,* 45 (December, 1961), 412–417.

[15] W. James Popham and Joseph M. Sadnavitch, "An Evaluation of Filmed Science Courses in Public Secondary Schools," paper read at the Annual Meeting of the American Educational Research Association, Chicago, Illinois, February 24, 1961, *Science Education,* 45 (October 1961).

"Hawthorne Effect," would seem to indicate that when the instruction via films is purposeful and planned in terms of objectives to be reached, positive increments in learning occur. One might also say that films should not replace the regular mode of instruction or the role played by the instructor. Teaching with or without films, television, or machines, will be effective only as we employ teachers who know their subject matter and have the know-how to put the material across. A good teacher may greatly augment his effectiveness by the proper use of mechanical aids. This means selection of good films, good television programs, and good teaching-machine programs, which fit into a planned and purposeful program of instruction, the objectives of which are known by both the teacher and her students and which are above the fact-knowing level or which are challenging to both parties in the instructional process. Without these considerations, the process of learning is no better off than it was before the day of mechanical aids.

In conclusion, I quote:

> Generally, studies in educational television give little or no consideration to the factors enumerated above. As a result, an individual has difficulty in determining their meaning. It is even conceivable that the effects of television teaching are to limit seriously the amount of learning that takes place in the classroom but that this deleterious effect is sometimes compensated for by the tutoring and the extra motivation which the procedure invokes. While this is an extreme hypothesis which probably should not be taken seriously, its compatibility with the findings in current studies in the area of educational television point to the deficiencies of such research.[16]

[16] Robert S. Soar, "Evaluating Educational Television," *The University of South Carolina Education Report,* 4 (December, 1960), 3–4.

A COMPARISON OF INDUCTIVE AND DEDUCTIVE METHODS OF TEACHING HIGH SCHOOL CHEMISTRY *

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A STUDY of the comparison of inductive and deductive methods of teaching high school chemistry was made during the years 1948–1958. This investigation will be reported here in the two phases in which it was undertaken, each based on a null hypothesis as follows:

Phase I. There is no statistical difference between the mean score on the spring administration of the Anderson and Cooperative [1] chemistry tests taken by students inductively and deductively taught, and of matched intelligence.

Phase II. There is no statistical difference between the mean scores of inductively and deductively taught classes of matched intelligence in the understanding of chemical equation-balancing.

Definition of Terms. Deductive, descriptive chemistry, as used in this paper, means the traditional type of chemistry course in which theory and descriptive chemistry are given in the classroom lecture. Laboratory manuals in the hands of the students are meticulously followed by them in order to perform the experiments already discussed in class.

Inductive chemistry signifies that type of teaching in which class work covers theory only and this theory itself is presented in such a way as to elicit student

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[1] *Anderson Chemistry Test.* Yonkers-on-Hudson, N. Y.: World Book Co., 1950. *Cooperative Chemistry Test, Form X.* Princeton, New Jersey: Cooperative Test Service, 1947.

response throughout, thereby making the laws and theories a matter of student discovery rather than an empirical memorization. Laboratory work stresses the investigative approach and is performed without the detailed directions, latitude being given for independent problem-solving.

Procedure—Phase I. Twelve classes in three schools were used in this study; three teachers and four hundred and thirty chemistry students of grade eleven college preparatory classes made up the test sample. Six classes were taught inductively and six deductively. All teachers used the same syllabus, text, and tests, and kept to the same time schedule. Final comparisons were based on results on two standardized chemistry tests. Intelligence test records [2] of all students were obtained, and application of the t-test failed to reveal any significant difference among the I.Q.'s of the several classes.

The syllabus taught included the following nine basic topics:

Atomic and molecular structure
Periodic table and classification
Simple equations and the laws involved
Stoichiometric problems
Solutions, suspensions, emulsions and colloids
Acids, bases and salts—ionization
Oxidation-reduction
Gas laws
Radioactivity and nucleonics

In addition, knowledge of the chemistry of the following elements and compounds was required:

Oxygen
Hydrogen
Water
Alkali metals and their common compounds
Halogens and hydrohalides
Sulfur and sulfides
Nitrogen and its compounds
Carbon and carbon dioxide

The deductive classes worked on all material in class, then repeated the descriptive sections in the laboratory. The inductive classes limited their classroom discussions to the first nine topics and handled the descriptive chemistry entirely in the laboratory.

In no instance was the deductive descriptive method found to be superior to the inductive approach, hence, it was concluded that students taught inductively are able to grasp factual chemical knowledge and fundamental chemical concepts better than deductively taught students, that is, students taught by the traditional methods.

Calculations based on the above data give a t-value of 7.03 for the Anderson test and 4.12 for the Cooperative, both significant at the one per cent level of confidence.

[2] California Test of Mental Maturity, advanced form, California Test Bureau, Los Angeles, California, 1946.

THE T-TEST APPLIED TO SCORES ON THE ANDERSON AND THE COOPERATIVE CHEMISTRY TESTS, INDUCTIVE AND DEDUCTIVE CLASSES

Deductive				Inductive				
Mean (1)	S.D. (2)	S.E.$_M$ (3)	N (4)	Mean (5)	S.D. (6)	S.E.$_M$ (7)	N (8)	Type (9)
56.88	16.62	2.85	240	71.23	13.30	2.22	240	Anderson
60.00	10.32	1.54	240	70.05	12.17	2.22	240	Cooperative

LOWER QUARTIVE INTELLIGENCE GROUPS—ANDERSON AND COOPERATIVE CHEMISTRY TEST SCORES

Deductive			Inductive			
Mean (1)	S.D. (2)	N (3)	Mean (4)	S.D. (5)	N (6)	Type (7)
46.16	16.90	52	59.32	13.58	52	Anderson
52.64	14.13	52	71.87	13.42	52	Cooperative

The t-values calculated on the above data were t=4.52 for the Anderson and t=7.36 for the Cooperative chemistry test.

UPPER QUARTILE INTELLIGENCE GROUPS—ANDERSON AND COOPERATIVE CHEMISTRY TEST SCORES

Deductive			Inductive			
Mean	S.D.	N	Mean	S.D.	N	Type
(1)	(2)	(3)	(4)	(5)	(6)	(7)
66.16	11.01	52	79.14	7.76	52	Anderson
86.08	6.27	52	72.87	10.28	52	Cooperative

The t-values, significant at the one per cent level of confidence, are 7.17 for the Anderson and 5.06 for the Cooperative chemistry test.

An effort was then made to determine whether the lower-intelligence group of students worked as effectively under inductive methods of instruction. Upper and lower quartiles of I.Q. were separated and their scores on the Anderson and Cooperative tests compared. In every instance the inductive groups performed significantly better, as measured by these standardized tests.

One possible explanation that suggests itself is that five periods per week spent on theoretical chemistry unencumbered with memorizable facts gives a student a more solid foundation from which to reason out chemical problem-situations. Laboratory work which is not a mere repetition of classwork already covered is more interest-compelling and hence motivates a pupil to a greater degree of learning. Slow students are compelled to read some work before coming to laboratory sessions in order to be able to produce even a bit of laboratory experimentation; they are also forced into more class participation than under the deductive method, and, moreover, in a discussion type of class, the slow pupil cannot let his mind wander as easily or as frequently as in straight lecture classes.

SUMMARY

1. A study of the comparison of inductive and deductive chemistry teaching at the secondary level was made during the years 1948–1956.

2. This phase of the study involved twelve high school classes. Eight were classes of thirty-five girls each, in one urban high school in Massachusetts. Two classes of thirty-five students each were located in an urban center in Ohio; and two more classes were in a city in the West Indies. Half the classes were taught inductively and half deductively.

3. The same teacher taught both inductive and deductive classes in the same school, thus limiting teacher motivation variation to a minimum. All teachers followed the same outline for class presentation of the topics. All administered the same tests.

4. All students following the inductive procedure used the same laboratory guide sheets designed by the writer. All students following the traditional deductive methods used the same semimicro laboratory manual sheets designed by the writer.[3]

5. The California Test of Mental Maturity, advanced form, was administered to all students involved in the study. Critical ratios applied among the means-standard deviations of the intelligence test scores failed to reveal any significant difference in mental ability, hence variation in chemistry achievement was possibly the result of variation in method of teaching.

6. The Anderson chemistry test was administered to each class in April of the school year. The Cooperative chemistry test, form X, was administered in May. The t-test was applied among the means-standard deviations of scores on the Anderson Chemistry Test in each school, and then among the three schools, and a significant difference in favor of the inductive approach

[3] Sister Ernestine Marie O'Connell, S.C.H., *Semimicro Chemistry for High School.* Newark, New Jersey. Washington Irving Publishing Company, 1950.

was found in all cases. The same held true of the Cooperative chemistry test.

7. In no instance was the deductive approach found to be superior to the inductive approach even at the five per cent level of confidence.

Conclusions. Inductive laboratory teaching produces higher achievement at the one per cent level of confidence on the Anderson and Cooperative chemistry tests than does deductive teaching.

1. After a year's course in general chemistry, inductively taught students have a more thorough knowledge of chemistry as measured by the Anderson and Cooperative chemistry tests than do deductively taught students.

Implications. The further advantages of the inductive approach in terms of increased chemical knowledge warrant investigation.

2. An inductive course of studies designed by one person can, with success, be followed by others. The two teachers involved in this phase of the study were in close contact with the writer. Further study should be undertaken to determine if total strangers could satisfactorily follow the written suggestions and directions for the inductive approach.

3. An inductive approach is more demanding on the resources of the teacher. The amount of chemical background required of a teacher in order to be successful in this field merits more research.

4. Tests designed to measure chemical achievement at the secondary level are few. More investigations should be done in the field of testing the understanding of chemical concepts.

5. The writer feels that further studies should be made in the realm of comparison of inductive and deductive methods in relation to extrinsic measures such as correct habits of observation, ability to reason, and the acquisition of scientific attitudes and interests.

Phase II. This was a large-scale study of the unit on chemical equation-balancing and involved thirty-four schools, fifty-six classes, thirty-nine teachers and eighteen hundred pupils of grades eleven and twelve college preparatory groups in the Eastern half of the United States. Each teacher was supplied with a unit-outline, lecture and laboratory notes, guide sheets, pre-test and post-test sheets. Twenty-eight classes were taught inductively and the other twenty-eight deductively. The overall pre-test scores for all deductively taught classes was 11.6 while the overall post-test scores for the same classes was 13.4. Inductive classes had a mean pre-test score of 11.6 also, but a post-test mean of 16.0, showing a gain of 4.3 test points over 1.8 for the deductive groups. Treated from a statistical viewpoint, the application of the t-test shows a value of 7.2 for deductive classes and 20.7 for inductive classes, both significant at the one per cent level of confidence. However, both classes did benefit from the teaching of the unit. Was the inductive gain significantly superior to the deductive gain? The null hypothesis to be tested was: Inductive and deductive teaching of the unit on equation-balancing produce results that are not significantly different. The t-test was used again as a measuring tool and a value of 13.6 was obtained, indicating superiority of the inductive method, which superiority is significant at the one per cent level of confidence.

The question might arise: were the classes alike in basic mentality? As measured by a standardized intelligence test,[4] yes, as the application of the t-test to the mean scores of the I.Q.'s of the classes involved failed to reveal any significant difference. Hence, since pre-test scores were alike and I.Q.'s showed no significant variation, the classes were assumed to be similar in intelligence and basic chemical knowledge and that difference in performance on the final test might be the result of variations in method of teaching the unit.

[4] *Otis Quick Scoring Mental Ability Test.* Gamma. Yonkers-on-Hudson, New York: World Book Company, 1937.

The t-test was used throughout the second phase of the study as a measuring tool, and was calculated from the less familiar formula [5]

$$t = \frac{M_I - M_D\,^*}{\sqrt{\frac{\Sigma d^2}{N(N-1)}}}$$

* Explanations of terms at end of paper.

better in imparting the chemical knowledge as measured by the Symbolic Unit Test on equation-balancing.

The results of t-tests applied to the Symbolic Unit Test scores indicate that the inductive method is statistically superior to the deductive-descriptive method with average classes, with students in the lowest quartile in intelligence, and with students in the highest quartile in intelligence, in the mastery of the concepts of chemical equation-balancing.

APPLICATION OF THE T-TEST TO PRE-TEST—POST-TEST SCORE GAINS ON SYMBOLIC UNIT TEST, INDUCTIVE AND DEDUCTIVE CLASSES

Score Summations				Formula Applications	
	Deductive	Inductive			
	(1)	(2)			(3)
ΣX	6829	6931	← pre-test	ΣD	7649
ΣY	9272	12137	← post-test	ΣD^2	1327783
ΣX^2	89332	90477	← pre-test	Σd^2	1279430
ΣY^2	141768	244732	← post-test	M_D	4.3
ΣXY	105211	140529		M_I	9.0
N	605	605		t	5.05
M_{pre}	11.1	11.2	Pre-mean		
M_{post}	15.4	2L.2	Post-mean		

Since the lower quartile intelligence group is of interest in showing whether or not inductive teaching can be absorbed by slower pupils, the following data on this group were collected:

MEANS-STANDARD DEVIATIONS OF THE LOWER QUARTILE INTELLIGENCE, SYMBOLIC UNIT TEST SCORES, INDUCTIVE AND DEDUCTIVE CLASSES

Deductive		Inductive
11.5	post-test	14.7
10.8	pre-test	10.7
0.7	difference	4.0
2.7	S.D.	2.5
125	N	125
11.5	post-test mean	14.7
	t-value=14.5	

Using 250 df as the closest value with which to enter tables, the t-value is found to be significant at the one per cent level of confidence, and, since this value is significant, the null hypothesis is rejected in the case of the lower quartile intelligence pupils. Inductive teaching is significantly

Summary. A study of inductive and deductive methods of teaching the secondary school unit on equation-balancing in chemistry was made during the 1957–1958 school year.

2. This phase of the study involved thirty-four schools and fifty-six classes. Classes averaged twenty-five students each and were located in cities across half the nation. Half the classes were taught inductively and the other half deductively, all with lecture notes, laboratory out-

[5] E. F. Lindquist, *Statistical Analysis in Educational Research.* Boston: Houghton-Mifflin Company, 1940 p. 59.

lines, guide sheets and unit outlines supplied by the writer. All teachers followed the same time schedule, used the same demonstrations and gave the same tests. The test was administered before and after teaching of the unit and all tests were sent to the writer for scoring.

3. A mental ability test was given to all students participating in the study.[6]

4. Critical ratios were applied among the means-standard deviations of the intelligence test scores. These failed to reveal any significant variation in intelligence, hence, variation in chemistry achievement is possibly the result of variation in method of teaching.

5. The appliaction of an F-test[7] to deviations of pre-test scores failed to reveal any significant differences in means of inductive classes, hence these classes were pooled for further study. All deductive classes were likewise pooled for testing against inductive classes.

6. A t-test was applied to the Symbolic Unit Test score differences between pretests and post-tests in all inductive and deductive classes. This test revealed the superiority of the inductive method (at the one per cent level of confidence.)

7. By the single group method[8] it was shown that there was a significant difference between pre-test and post-test scores of the upper quartile intelligence groups of inductive and deductive classes.

8. By the difference method[9] a t-value was obtained for the post-test scores of inductive and deductive groups of the upper quartile intelligence groups. This test indicated the superiority of the inductive method at the one per cent level of confidence.

[6] Otis Quick Scoring Test of Mental Ability, *op. cit.*

[7] E. F. Lindquist, *Statistical Analysis in Educational Research*. Boston: Houghton Mifflin Company, 1940, p. 72.

[8] Henry Garret, *Statistics in Psychology and Education*. New York: Longmans Green and Co., 1953, p. 429.

[9] Henry Garret, *op. cit.*, p. 437.

9. The t-value was obtained for the post-test scores on the lower quartile intelligence group, inductive and deductive classes, on the Symbolic Unit Test on equation-balancing. A significant difference at the one per cent level was found to exist in favor of the inductive group.

Conclusions. Inductive laboratory teaching produces higher achievement at the one per cent level of confidence on the Symbolic Unit Test on equation-balancing than does the deductive-descriptive teaching.

2. Inductively taught students of both upper and lower quartile intelligence groups surpassed those taught deductively, this superiority being significant at the one per cent level of confidence, hence, it was concluded that students taught inductively are apparently able to grasp the fundamental concepts of equation-balancing better than students taught by the deductive-descriptive method.

3. Consistent results in favor of the inductive method indicate that directions supplied by one teacher can be satisfactorily followed by other trained chemistry teachers.

Symbolic Unit Test. The test administered before and after the unit was a unique departure in test construction, being a combination of diagram and verbal statement, thus coupling the laboratory experimentation with the theoretical question. The test was designed with the hope of testing the understanding of the concepts of equation-balancing instead of giving bonuses to those who are good memorizers. The answers to the questions were not difficult, nor were the questions themselves intended to be subtle. Responses were made by checking off the proper answer on a printed answer sheet which accompanied the mimeographed test question sheet.

The test comprised thirty-six items and was analyzed for difficulty and discrimination of the items, these calculations being based on the top and bottom twenty-seven

per cent of the sample.[10] A one thousand paper sample served for the first determination and a random hundred of the remaining papers was selected to make a check. The difficulty index is the proportion of testees making the correct response, correction being made for chance. Difficulty indices ranged from 0 to 100. The discrimination index, a measure of the discriminatory power of an item, was reported as the biserial coefficient of correlation between the item and the total score exclusive of that item. Discrimination indices of 20 and above were considered adequate for this type of achievement test. In the final analysis five items fell short of the desired goal. Reliability was determined by the method of rational equivalence.[11]

* Explanation of symbols: X=pre-test scores; Y=post-test scores; N=total no. students involved; $\Sigma D=\Sigma Y-\Sigma X$; $\Sigma D^2=\Sigma X^2+\Sigma Y^2-2\Sigma XY$ $\Sigma d^2=\Sigma D^2-\frac{(\Sigma D)^2}{N}$; M_D=mean gain of deductive group; M_I=mean gain of inductive group from pre-test to post-test.

which endeavors to get an estimate of the reliability of a test by stressing intercorrelation of items with the test as a whole and bases its calculations on the proportion of correct and incorrect answers for the individual test items. This coefficient was calculated to be 0.61. The pre-post Test coefficient of correlation is 0.51. The ceiling of the test was not reached by any testee.

GENERAL CONCLUSIONS

The two phases of this study have yielded results which corroborate each other. In Phase I, twelve classes in three schools were used in an effort to determine the existence of significant differences in achievement in the field of high school chemistry under inductive and deductive methods of teaching. Results were judged from scores on two standardized chemistry achievement tests. The results affirmed the superiority of the inductive method which superiority was significant at the one per cent level of confidence for average classes, for upper and for lower quartile intelligence groups.

Phase II of the study made use of more than fifty classes in thirty-two schools and determined the effect of inductive and deductive teaching methods on one unit of high school chemistry—equation-balancing. Again, at the one per cent level of confidence, inductively taught classes were superior. Judgments were made on the basis of scores on a symbolic unit test designed by the writer. This test itself measured up to the requirements of a valid tool for the measurement of achievement of chemical equation-balancing.

[10] Frederick B. Davis, *Item Analysis Data.* Cambridge, Massachusetts: Harvard Education Press, 1949.

[11] Henry Garrett, *op. cit.*, p. 335.

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SOME PHASES OF RESEARCH IN THE DEVELOPMENT OF A GENERAL EDUCATION COLLEGE CHEMISTRY COURSE *

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DETERMINING THE CRITERIA FOR A GENERAL EDUCATION COLLEGE CHEMISTRY COURSE

Introduction

The guiding philosophy for the course was developed in the preceding chapter. This chapter will be devoted to a brief discussion of the criteria selected which may be used in evaluating the experiences of the course which follows.

The definition of a criterion according to Carter V. Good is, "A standard, normal or judgment selected as a basis for quantitative and qualitative comparison." [1]

The following criteria were selected on the basis of this definition:

1. The criterion of relatedness.
2. The criterion of flexibility and variability.
3. The criterion of continuity.
4. The criterion of interaction.
5. The criterion of harmony.
6. The criterion of effectiveness.

These criteria in their application in developing a first-year general education college chemistry course are discussed briefly in the paragraphs which follow.

The Criterion of Relatedness

Several ideas are involved in this criterion: first, relatedness in the sense that each unit or part of the course is related directly to the basic assumption of the course, namely, the atomic structure of matter and the behavior of matter as related to it; secondly, the inner relatedness of each part of the course to each other part. Other phases are also considered such as how each part of the course is related to the needs of the student in society and how each concept is related to the importance which chemistry plays in the life of each individual. Another and perhaps a major part of this criterion is the relatedness of each new idea to the past experience of the student. In other words, does the course utilize maximum student experiences in relating each new concept?

The Criterion of Flexibility and Variability

Is the course sufficiently inclusive to cover adequately the concepts necessary for both the general education student and the student who plans toward further specialization? Is the course sufficiently comprehensive and so arranged as to provide for the individual differences of the students? Are there sufficient concepts to form a basic course for all students and still enough additional concepts to provide enrichment for the student who has the abiltiy and in-

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[1] Carter V. Good, *Dictionary of Education.* New York: McGraw-Hill Book Company, 1945, p. 110.

terest to delve deeper into the parts which appeal to him? Is the course so planned that adjustments can readily be made to a particular group of students or to the environmental factors in the immediate vicinity? Does it allow for the use of environmental factors?

The Criterion of Continuity

Is there a logical sequence in the arrangement of the course experiences? Is the course a continuous series of exciting adventures for the student with each new experience depending upon the past unit or idea so that the student develops the feeling that he is building, so to speak, upon the foundations he has laid in the past? Brubacher says, "The challenge to the intellect is to employ the familiar as a means of exploring the novel and bringing it under control in order to meet future novel situations." [2] This must be a continuous process throughout the course.

The Criterion of Interaction

Do the experiences of the course allow for a maximum interaction between the students and the instructor, between the student and other students, between student and his environment? Does the course develop in the student a feeling of active participation instead of the feeling that he is just a passive recipient of some type of spoon feeding?

The Criterion of Motivity

Does the student taking the course have the feeling that he is learning that which is of real value to him? Is he led to a desire to delve deeper into the study of the structure and behavior of matter because they are of real interest to him? Does the interest and enthusiasm the student feels in participating in the course tend to help interest others in the course?

The Criterion of Harmony

Several phases of this criterion are considered as paramount importance in the development and evaluation of the course. First, and most important, is the course in keeping with the basic objectives and philosophy of science? Is everything in the course in agreement with all that is known about the structure and behavior of matter? Is each part related to the past and succeeding parts? Not only does each part need to be related to other parts, but each new concept should be an outgrowth of part experiences.[3]

The second phase of harmony has to do with method. Are the methods used in teaching it in harmony with what is known about learning? Is the student led to use the facts at hand and his past experience to evaluate each new experience, accepting or rejecting it on the basis of his findings? Is he led to be objective in his thinking, seeking new evidence to support or discredit his conclusions? Do his conclusions from all the facts and concepts studied harmonize with his past experience? Is the course so conducted that he will use it in predicting and evaluating new experiences? In other words, are the course experiences and the methods used of such a nature that the student actually lives the course? Does he make it a dynamic part of his method of thinking so that what he learns is useful to him throughout his life?

The third phase of this criterion of harmony is that of harmony with democratic processes. Is the course arranged and taught in such a way that the student de-

[2] J. S. Brubacher, *Modern Philosophies of Education*. New York: McGraw-Hill Book Company, 1939, p. 327.

[3] The philosophy of science and education and a checklist of the objectives used in the development of the course and with which the course must harmonize in order to stand the test of the criterion of harmony were discussed earlier in the study. Luther A. Arnold, "The Development of a General Education College Chemistry" Ed.D. disseration, microfilmed, School of Education, University of Florida, 1955.

velops the feeling that his individual welfare is always of first importance? Is he made to feel in his course work that he is important as an individual and also as a member of the group?

The Criterion of Effectiveness

The final test of the course is its effectiveness in developing objective thinking on the part of the participants. The term participants is used here rather than students to connote the idea of sharing. All students must be made to feel that they are active participants in the course experience if it to be of maximum effectiveness. Furthermore, to be effective, the course must succeed in helping the student develop a sound philosophy of life based upon sound thinking and good judgments. Finally, the effectiveness of the experiences may be judged on the basis of the extent to which the thinking of the student has been slanted toward a continuous improvement of man's relations to his fellow man.

DETERMINING THE BASIC ASSUMPTIONS

The frame of reference alluded to throughout the discussion is that of the greatest value for the individual in a dynamic society in a dynamic universe. The ever-changing concepts man has of his environment and his relationship to it necessitates a lack of finality. A constant re-evaluation of knowledge and learning, with better life in view for each one, becomes necessary.

If we accept a scientific approach in attempting to establish any course for the greatest good for the most people, consideration must be made for this ever-changing theoretical nature of educaiton. Certain basic assumptions should be made in keeping with the best theories available. Remembering that assumptions also are subject to constant re-evaluation by each individual in the light of his past experience, such assumptions must lack definiteness. They may be sufficient unto the day when they are formed, but insufficient unto the morrow.

It is in the light of the foregoing observations and in keeping with accepted philosophy of education that four assumptions are made for this course in general education chemistry.

The first assumption is that in our democratic society objective thinking based upon an understanding of the structure and interaction of matter leads to a better life and should, therefore, be a part of the education of all.

The second assumption concerns the function of general chemistry teaching. The chief function of a general education college chemistry course is to provide experience in objective thinking regarding the structure and interaction of matter.

The third assumption is that one learns most effectively when new learnings are associated with past experiences in a way that is meaningful to the individual and when the individual sees that they may be used for the purpose of controlling, predicting, and testing future experiences.

The fourth assumption is that a general education chemistry course should begin with the modern atomic theory and be developed upon it.

In the first assumption, the implication is that everyone needs to participate to the fullest extent in making sound and intelligent decisions. In the second assumption it is pointed out that to make sound decisions one must be free from fears and superstitions. Ability to think objectively on the basis of knowledge and understanding of cause and effect relationships dispels fears and superstitions, and enables one to predict future experience on the basis of past experience. Haphazard conjecturing regarding possible consequences of one's decisions will be avoided and intelligent decisions will result.

The third assumption is not unique to

a course in general education chemistry; it is basic to all education. It involves our method of learning. According to Dewey, "It is that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experience."[4] After showing how a child, through impulse, has experience through which he learns, Dewey continues with this statement which is directly applicable to chemistry teaching:

> The acts by which a scientific man in his laboratory learns more about flame differ no whit in principle. By doing certain things, he makes perceptible certain connections of heat with other things, which had been previously ignored. Thus his acts in relation to these things get more meaning; he knows better what he is doing or "is about" when he has to do with them; he can *intend* consequences instead of just letting them happen—all synonymous ways of saying the same thing. At the same stroke, the flame has gained in meaning; all that is known about combustion, oxidation, about light and temperature, may become an intrinsic part of its intellectual content.[5]

This implies that the student must understand what is being done in the course. Some learning is gained by any experience even if imposed from without. Fuller learning, however, comes with concern as to outcome. Careful observation, with purpose, leads to anticipation of the outcome and makes it meaningful. Provision for relating all new concepts to the past experience of the learner in such a way that he grasps the relationship in terms of his past experience should be embodied in a general education chemistry course. Because of the individuality of experience, the presentation must relate new concepts to general experiences shared by the largest possible number of students to make the new concepts meaningful. It is also implied that the course must result in a logical arrangement of generalizations with each new concept related to the earlier concepts. It must be borne in mind that the student interprets new concepts in the light of his past experience and that only as he finds them meaningful does he accept them. Once he accepts them as integral part of his experience, he may use them to evaluate and interpret other new experiences. Motivation or the desire to learn is implied in that the student learns that what his experience dictates is worthwhile or what he sees has value to him. The course must give the student opportunity to test or evaluate the assumptions himself so that in the light of new experience he may change these assumptions or discard them entirely if his evaluation proves them wrong. He should be given the opportunity for rewarding participation in the activities of the course. Therefore, the course should not be a formal lecture course but one designed to allow the greatest possible amount of student self-expression. It is further implied in this assumption that the course be adjustable to variation in student abilities, providing extra activities for those of greater learning ability or special interests.

The atomic theory, the fourth basic assumption, is taken as a basis for constructing the course. A theory is a plausible hypothesis accepted as an explanation for some phenomena. Until evidence arises to indicate it to be inadequate, it serves as a starting point for investigations regarding the phenomena. It will be subjected to constant re-evaluation. If evidence proves the theory insufficient to explain the phenomena, it is revised or discarded. The revised or new theory is then subjected to further testing and the process is repeated. Since its conception, as early as the fourth century B.C. when the Greek Democritus first proposed that all matter was composed of indestructible particles (atoms), the atomic theory has undergone many changes or revisions in the light of newly discovered evidence. Today, the atomic

[4] John Dewey, *Democracy and Education*, New York: The Macmillan Company, 1916.
[5] *Ibid.*, p. 90.

theory, with its many revisions, is so generally accepted by leading scientists from all parts of the world that it is generally thought of as a law. It is accepted as the best explanation of the structure of matter and all chemical changes that take place in our natural environment. In using modern atomic theory as a basic assumption, it must be remembered that, though at present it is the best explanation available, some aspects of it are assumptions and that it may continue to be revised or even discarded in the light of new discoveries. The student should be helped to understand this point and to approach it with an open, scientific mind.

A long recounting of the historical development of modern atomic theory would be tedious and unnecessary for the average student, but the student who evidences interest in it should be given opportunity to investigate it. Most any recent chemistry text book may be consulted, or a number of excellent reference sources should be made available to such an interested student. The atomic theory as accepted today will be assumed as adequate for the purposes of this course, designed for the general education student and the student who wishes to specialize.

Briefly, the modern atomic theory includes all the recent theory regarding the structure and behavior of matter and is not limited to the basic particle concept of atoms as Democritus conceived it or as it was later revised by John Dalton. Today the theory that matter is conceived as being made up of combinations of atoms, ions, and molecules is accepted, but we are additionally concerned with the basic structural units of the atoms themselves. It is therefore assumed that electrons, protons, neutrons, and the dozen or more other atomic structural parts exist. The oneness of matter and energy is further assumed. The chief emphasis, however, will be upon the electrons, protons and neutrons whose assumption enables one to explain differences in structure and interaction of matter in all ordinary chemical processes or changes.

A course in general education college chemistry may be likened to a well-planned educational tour across the country in a specially chartered bus. The group prepares for the tour by preliminary work with an expert guide. The members of the group are made to feel that the tour is for their enrichment. The guide must be one familiar with a logical sequence of of experiences which promise excitement and interest for the participants. A carefully-planned itinerary with the necessary equipment is necessary for a successful tour. The guide must be aware of places where side trips from the regular route would be of particular interest and benefit to the group and allow digressions to satisfy these interests. Such side excursions would lead to changes in the itinerary if the interests of the group indicated their feasibility. Normally, a group will exhibit a wide variety of background of experience and interest. Each member will observe and glean from the tour according to his past experiences. New interests will be developed as new experience become a part of him.

It is not necessary for each member to be familiar with the historical or technical development of his conveyance. It is taken for granted that the vehicle will bring him to the desired destination. The guide, however, who also serves also as driver, must know the mechanics of the conveyance and know whether or not it is functioning properly. Should the need arise, the help of the more mehanically-minded passengers may be solicited.

A guide with a tour properly planned and sufficiently advertized will find his passengers enthusiastically and eagerly anticipating the excursion into new and unfamiliar territory. His own enthusiasm

becomes heightened as he realizes that there are added experiences in store for him with each tour. The better he learns to understand his passengers, their interests and enthusiasms, the more successful his tours will become. He will be aware that special expert guides who are familiar with particular areas along the route can make the sojourn more meaningful to his patrons.

The improved and tested atomic theory is the vehicle which will convey the general education student on his tour into the structure and change of matter. The instructor is the guide. He will use this new model atomic bus to search out and relate phenomena to principles and concepts which make them meaningful to the the student. He will recognize the value of demonstrations and experiments. He will make liberal use of charts, diagrams, space models, and sketches. Carefully-selected problems of application as means of making new concepts meaningful, participation in science fairs, preparing demonstrations and exhibits for maximum student activity are essential to individual interest and understanding. He will discard the outmoded idea that his "passengers" possess a type of "cranial sponge" which absorbs the guide's concepts gleaned from personal experiences and which he, so to speak, pours into these "cranial sponges" by means of lectures. His role as a well-informed understanding person who will guide the student toward personal gain and satisfaction is the key to a successful tour. For maximum benefit and greatest gain, the student must assume his share of responsibility and participate to the fullest extent.

All conceivable matter is discontinuous, made up of separate particles—atoms. Of the one-hundred known kinds of atoms, each has its own characteristic structure and properties. The structure and properties of each determine what combinations it will make with other atoms. Changes in atomic combinations are constantly taking place, making other combinations and accounting for all change in matter. The oneness of matter and energy as they are related to Einstein's equation $E = mc^2$ is evident in such new developments as the atom bomb, the hydrogen bomb, atomic energy and radio-activity.

The theory presently accepted which best explains these phenomena and their relation to the structure of matter is what is referred to as the atomic theory. For the purpose of this course, its development and proof is assumed. A brief unit dealing with some of the basic fundamental parts is used as a starting point for the course and these principles are used as the basis for the whole course. Each generalization may serve to relate phenomena in our physical environment to this basic assumption. By so doing, the student should have the benefit of the feeling that he is embarking immediately upon the exhilarating venture of learning about and using the atomic theory. Tedious review of the history and development of the theory would dull his enthusiasm. Clarification of such concepts as matter, energy, ions, acids, as they arise in the sequence of the course is deemed the best procedure. Each generalization can be used as an assumption. There is opportunity for checking it in the light of the atomic theory and other supporting evidence from past and current experiences.

A course such as this would not use a text as a rigorous guide but as a reference source. The course would make liberal use of class demonstrations and laboratory experiments, allowing fullest participation by students. An instructor who has used demonstrations associated with discussion of the principles recognizes that added interest and understanding result. Students exhibit more interest and enthusiasm if they anticipate demonstrations and participation as well as discourse. The field which will be covered may well be smaller, but the reward of growth in understanding and objective thinking will be great enough to compensate for the sacrifice entailed. The emphasis will be on dynamic activities

in laboratory and discussion rather than on formal lecture. The instructor should assume the role of guide, indicating the phenomena which students will wish to investigate without assuming the authoritarian attitude. In other words, he must be an expert in teaching as well as an expert in chemistry.

To develop suitable laboratory procedure for such a course could form the basis for another study. At the University of Florida such a laboratory study is being developed. In this procedure, the student has opportunity to study the concepts involved and then perform an experiment supporting or establishing this concept. The student then checks immediately with the instructor and receives his approval when there is evidence that an understanding has been gained. Another type of laboratory procedure would be one in which there is combination of instructor demonstrations and individual laboratory experiments. The students might face the instructor and perform their own experiments individually as the instructor performs and demonstrates. Each of these methods has the advantage of keeping the students together on a concept until an understanding of its basic principles has been gained. The blind recipe type of laboratory experimentation in which each student performs experiments by following printed directions, often without the necessary preliminary understanding of what is being done and why, does not offer this advantage. The student must be led to feel that the laboratory experiments are not separate from the course, but are an integral part of it, where first-hand observations are made which support or disprove the basic assumptions or generalizations.

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NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

PROGRAM—34th ANNUAL MEETING

THE PICK-CONGRESS HOTEL, CHICAGO, ILLINOIS

February 22, 23, 24 and 25, 1961

AND

JOINT MEETINGS WITH THE COUNCIL OF ELEMENTARY SCIENCE INTERNATIONAL AND THE AMERICAN EDUCATIONAL RESEARCH ASSOCIATION

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1960–61

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Executive Committee Member, EDWARD K. WEAVER, Atlanta University, Atlanta, Georgia

Executive Committee Member, PAUL BLACKWOOD, Office of Education, Washington, D. C.

NARST MEETING SCHEDULE

WEDNESDAY, FEBRUARY 22

1:15– 1:45 P.M.

Registration and Coffee.........Casino East

2:00– 4:30 P.M.

Contributed Papers ....Casino East

Presiding: DR. CLARENCE H. BOECK

1. *"Building a Junior High School Science Program."* NED E. BINGHAM, University of Florida, Gainesville.
2. *"Using the Scientific Approach in Building a Course of Study for High Schools in Egypt."* SAMI I. BOULOS, University of the State of New York, New Paltz.
3. *"Plant Communities—A Laboratory for High School Biology."* WILLIAM BENNET, Pensacola Junior College, Pensacola, Florida.
4. *"Highlights of Status and Trends in Science Teaching—Extracts from U.S.O.E. Studies."* LLOYD K. JOHNSON and RICHARD M. HARBECK, Office of Education, Washington, D.C.

Preview of films produced by the Department of Public Instruction of Pennsylvania on Space Travel for Use with Fifth and Sixth Grade Students.

Discussion: ALBERT F. EISS
Department of Public Instruction
Harrisburg, Pennsylvania

7:30 P.M. Annual Business Meeting—

Session I............Club House Annex

1. *President's Report,* CLARENCE H. BOECK, University of Minnesota, Minneapolis.
2. *Report on the Activities of the Cooperative Committee.* GEORGE G. MALLINSON, Western Michigan University, Kalamazoo.
3. *Report on the activities of Council on Research in Education.* KENNETH E. ANDERSON, University of Kansas, Lawrence.
4. *Relations with CESI.* JOHN D. MCLAIN, Public Schools, South Milwaukee, Wisconsin.
5. *Relations with NSTA.* J. DARRELL BARNARD, New York University, New York.
6. *Report of the Secretary-Treasurer.* HERMAN BRANSON, Howard University, Washington, D.C.
7. *Report of a Delegate to the TEPS Conference.* JOSEPH NOVAK, Purdue University, Lafayette, Indiana.
8. *Relations with the U.S.O.E.* PAUL BLACKWOOD, U.S. Office of Education, Washington, D.C.

9. *Report of the Research Coordinator,* ELLSWORTH S. OBOURN, U.S. Office of Education, Washington, D.C.
10. Discussion: Problems Facing the NARST.

THURSDAY, FEBRUARY 23

9:00 A.M. Improving Research in Science Teaching ....Casino East

Presiding: ELLSWORTH S. OBOURN

PART I: THE POTENTIAL OF THE RESEARCH RESOURCE CENTER

Invited Papers:

1. *"Avenues for the Improvement of Research."* KENNETH E. ANDERSON, Dean, School of Education, University of Kansas.
2. *Challenges to the Improvement of Research in Science Teaching."* WILLIAM W. COOLEY, Assistant Professor of Education, Graduate School of Education, Harvard University.
3. *The Purposes, Operation and Services of a Research Resource Center."* PAUL DEH. HURD, Professor of Science Education, Stanford University. JOHN G. READ, Professor of Science Education, Boston University

10:30 A.M. Round Table Discussions Casino East

PART II: CLINICS ON RESEARCH RESOURCE CENTERS

Association members in attendance will be arbitrarily assigned to a group. Each group will have a group leader and a group recorder and will consider the same list of questions. A written report will be presented by each group. The reports will be synthesized into a single report for publication.

Clinic Leaders:
CYRUS W. BARNES
FRED B. DUTTON
HARLEY GLIDDEN
H. CRAIG SIPE
EDWARD VICTOR
FLETCHER G. WATSON

11:30 A.M. General Session: Report by group recorders of clinic deliberations.

THURSDAY AFTERNOON, FEBRUARY 23

2:00 P.M. Report on Current Status of the NARST ....Casino East

Project on Unresolved Issues. W. Edgar Martin. U. S. Office of Education, Washington, D.C.
Presiding: ELLSWORTH S. OBOURN

PART III: SOME UNRESOLVED ISSUES IN SCIENCE EDUCATION

2:30–3:30 P.M. Panel Discussion: "The Crucial Issues"

Panel to be made up of a representative for each of the nine categories of issues. Five of the panel members will be round table leaders in the following sessions. Each panel member will be given from 5–10 minutes to discuss the issues uncovered in the area, list others that should be included, and to sharpen the focus on those which appear to be most critical.

Moderator: HERBERT A. SMITH, University of Kansas

Panel:

I. *Philosophy and Objectives* PAUL DEH. HURD
II. *Public Policy*......WILLARD JACOBSON
III. *Curriculum* ....J. STANLEY MARSHALL
IV. *Learning* ....JOHN C. READ
V. *Methods* ....ALFRED COLLETTE
VI. *Facilities and Equipment* JOHN S. RICHARDSON
VII. *Administration and Supervision* KENNETH E. ANDERSON
VIII. *Teacher Education*.....EDWARD VICTOR
IX. *Evaluation* ....JOSEPH NOVAK

3:45 P.M. Round Table Discussions on Categories of Issues most Frequently Selected by Research Resource Centers.

Categories and Leaders
Curriculum ....J. STANLEY MARSHALL
Methods ....ALFRED T. COLLETTE
Learning ....JOHN G. READ
Teacher Education ....EDWARD VICTOR
Facilities and Equipment.JOHN S. RICHARDSON

Each Round Table is to select a recorder. A plan and format will be suggested which will eventuate in a proposed plan for action. The details and summary will be worked out at the Office of Education from the recorders' reports. Copies will be sent to the moderator and all panel members.

5:00 P.M. Summary Statements (5 minute limit) from recorders for all five Round Tables.

THURSDAY EVENING, FEBRUARY 23

7:30 P.M. Second Business Session Club House Annex

1. *Report of Standing Committees*
   Audit
   Program
   Publication
   Nominating
2. *Report of Special Committees*

Discussion: Problems Facing NARST

3. *Election of Officers*
4. *New business*
5. *Adjournment*

FRIDAY MORNING, FEBRUARY 24

9:00 A.M. A Definition of Science Education Casino East

Panel Chairman: JOSEPH NOVAK

1. *Surveys and Status Studies.* ELLSWORTH S. OBOURN, U. S. Office of Education, Washington, D. C.

2. *Analytic Surveys.* KENNETH E. ANDERSON, University of Kansas, Lawrence.
3. *Experimental Studies.* MILTON PELLA, University of Wisconsin, Madison.
4. *Curriculum Research.* CYRUS W. BARNES, New York University, New York.

10:45 A.M. Contributed Papers...Casino East

Presiding: PAUL BLACKWOOD

1. *"A Ten Year Study Evaluating Fifty Student Teachers in Science and Mathematics in the Secondary School."* NATHAN WASHTON, Queen's College, New York City.
2. *"Report on a Six Year Science Motivation Project."* GEORGE G. MALLINSON, Western Michigan University, Kalamazoo.
3. *"Measured Differences in Identification Between Science Majors and Non-Science Majors at University Level."* THOMAS W. WEISS, Arizona State University, Tempe.

FRIDAY AFTERNOON, FEBRUARY 24

1:30 P.M. Contributed Papers...Casino East

Presiding: EDWARD K. WEAVER

1. *"In Favor of Discrimination."* MERVIN E. OAKES, Queens College, New York City.
2. *"The Principle-Unit-Project Method as Applied to the Teaching of Science."* L. M. COLYER, Kansas State College at Pittsburg, Pittsburg.
3. *"New Developments in High School Science Teaching."* MARGARET J. MCKIBBEN, National Science Teachers Association, Washington, D. C.
4. *"Readability and Comprehension of High School Physics Books."* J. STANLEY MARSHALL, Florida State University, Tallahassee.

3:30 P.M. Joint Meeting with the American Educational Research Association
Washington Room

Chairman: KENNETH E. ANDERSON

1. *"An Evaluation of Filmed Science Courses in Public Secondary Schools."* W. JAMES POPHAM, San Francisco State College, and JOSEPH M. SADNAVITCH, Northern Illinois University, DeKalb.
2. *"Evaluation of the Adapted White Physics Film in Turkey."* KENNETH G. NELSON, International Cooperation Administration, Turkey.
3. *"The Traveling Science Teacher Lecture Demonstration Program."* JERROLD WILLIAM MABEN, Michigan State University, East Lansing.
4. *"Improving Elementary Teacher Education in Science."* NATHAN S. WASHTON, Queens College, Flushing, New York.
5. *"The Biological Sciences Curriculum Study: The Development and Testing of a New Curriculum."* HILDA GROBMAN, University of Colorado, Boulder.

FRIDAY EVENING, FEBRUARY 24

7:30 P.M.

Open Meeting of the Executive Committee of NARST and the Issues Committee
Casino East

Plans for Action:
Research Resource Centers
Unresolved issues

1. *Report on Research Resource Centers.* Spokesman for Round Table Chairman: H. CRAIG SIPE.
2. *Report on afternoon Panel on Unresolved Issues.* Panel Moderator: HERBERT A. SMITH.
3. Discussion:
It is suggested that discussion might profitably be directed to such topics as:
A. Funds for Implementing Research
B. Communication and Clearing House Needs for Centers
C. Functions Served by NARST
(a) Design of projects
(b) Publicity and Public Relations
(c) Relation of such Organizing Activities as "Analysis of Research," "Publication of Digests," etc., to the Centers and to the Issues.

SATURDAY MORNING, FEBRUARY 25

Joint Meeting of the Council for Elementary Science International
and the
National Association for Research in Science Teaching

8:30 A.M.–9:00 A.M.

Registration ....Casino East

9:00 A.M.–10:30 A.M. Elementary School Science Investigations ....Casino East

Chairman: FRANK YOUKSTETTER
Wayne State University, Detroit, Michigan

1. *The Science Supervisor.* PAUL F. PLOUTZ, Coordinator of Science Education K-12, Livonia Public Schools, Livonia, Michigan.
2. *A Study of the Possession of the Abilities by Student Teachers in A Liberal Arts College Preparing to Teach in Grades 4–6.* BELLE D. SHAREFKIN, Brooklyn College, New York.
3. *An Examination of Selected Measures of Achievement and Aptitude for Use in Normative Grade Placement of Science Concepts on Light.* GARY R. SMITH, Wayne State University, Detroit, Michigan.

4. *A Study of Pupil Teacher Interaction in Planning Science Experiences.* Joseph Zafferoni, University of Nebraska, Lincoln.

CURRICULUM DEVELOPMENT FOR ELEMENTARY SCHOOL SCIENCE: IMPLICATIONS FOR RESEARCH

10:30 A.M. Orientation

William C. Forbes, Wayne State University, Detroit, Michigan.

10:45 A.M.–11:45 A.M. Concurrent Discussion Groups

Group I. *The roles of the teacher.* Brenda Lansdown, Brooklyn College, New York.

Group II. *The roles of the community.* William Forbes, Wayne State University, Detroit, Michigan.

Group III. *The roles of the administrator.* Albert Eiss, NDEA, Department Public Instruction, Harrisburg, Pennsylvania.

Group IV. *The roles of the science consultant or supervisor.* Al Piltz, NDEA, Washington, D. C.

Group V. *The roles of the outside consultant.* Willard Jacobson, Teachers College, Columbia University, New York.

11:45 A.M.–12:00 P.M. Reports of the discussion groups.

SATURDAY NOON, FEBRUARY 25

Luncheon ....Casino West

PROGRAM

TOASTMASTER

Clarence H. Boeck......*President of NARST*
University of Minnesota, Minneapolis, Minnesota

INTRODUCTION OF GUESTS

PRESENTATION OF CITATIONS
to
Samuel Ralph Powers
Ellsworth S. Obourn
Clarence M. Pruitt
in
Recognition of their Service
as
SECRETARY-TREASURER
and Clarence Harry Boeck
as
RETIRING PRESIDENT
by
Vaden Miles.......*Past President of NARST*

ADDRESS

"The Hero Image in Education"

Fletcher Watson ....*Graduate School of Education, Harvard University, Cambridge, Massachusetts*

National Association for Research In Science Teaching

The National Association for Research in Science Teaching is an organization devoted to the pursuit of research in curriculum organization, course content and teaching methods in the field of the sciences. Membership in the Association includes science teachers and administrators at all levels, elementary, secondary and college. The organization was founded in 1928, at Cambridge, Massachusetts.

NARST meets annually, usually alternating between an eastern seaboard location and a mid-western location. At the meetings, research papers in the field of science education are presented, along with symposia on topics of interests to teachers and educational research workers. Since 1947 the Association has included committees for the review of science education research at the elementary, secondary and college levels in cooperation with the U. S. Office of Education. The reviews have been published annually in *Science Education*, the official publication of the organization. Beginning with 1959 the reviews are to be completed on a biennial basis.

Membership in NARST is by nomination and election. The constitution provides for membership drawn from those active in research in science education, and those outstanding in science educational leadership. NARST is affiliated with the American Association for the Advancement of Science, and for the past several years has cooperated with the other science teaching organizations in sponsoring a program at the annual meeting of the A.A.A.S.

A REPORT TO THE NARST ON THE RELATIONSHIPS WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR THE YEAR 1960–61 *

GEORGE GREISEN MALLINSON

NARST Representative, Western Michigan University, Kalamazoo, Michigan

INTRODUCTION

THE report that follows encompasses three facets of the activities of the NARST. These are (a) the participation of your representative at the meetings of the Cooperative Committee, (b) the attendance of your representative at the meetings of the AAAS Council in New York at the Commodore Hotel on Tuesday, December 27, 1960 and Friday, December 30, 1960, and (c) the NARST Symposium held at the AAAS Convention on Tuesday, December 27, 1960.

ACTIVITIES AT THE MEETINGS OF THE COOPERATIVE COMMITTEE

During the year 1960–61 only one meeting was held by the Cooperative Committee, namely, in Washington, D. C., September 23–24, 1960. Because of an unprecedented snowfall, the meeting to be held in Raleigh, North Carolina in April 1960 was cancelled, and it was impossible to schedule another. However, the deliberations at the single meeting probably had greater implications than any two meetings held previously. The significance of this statement will be evident in the later paragraphs of this section.

I. Cooperative Committee Membership

At the time of presentation of this report the membership of the Cooperative Committee was as follows:

J. W. Buchta, American Institute of Physics, Chairman
C. L. Agre, American Chemical Society
John W. Cell, American Society for Engineering Education
Malcolm Correll, American Association of Physics Teachers
Seymour Fowler, National Association of Biology Teachers
Alfred B. Garrett, Board of Directors, AAAS
Phillip S. Jones, Mathematical Association of America
Robert T. Lagemann, National Science Teachers Association
Ralph Lefler, Section Q (Education) American Association for the Advancement of Science
Harry F. Lewis, Division of Chemical Education of the American Chemical Society
George G. Mallinson, National Association for Research in Science Teaching
John R. Mayor, Director of Education, AAAS
Bruce E. Meserve, National Council of Teachers of Mathematics
Fred H. Norris, Botanical Society of America
W. E. Restemeyer, Engineers Joint Council
Wayne Taylor, American Association for the Advancement of Science Academy Conference, Vice-Chairman
Bernard B. Watson, Secretary
Theodore Woodward, American Geological Institute

Present by Invitation:

William P. Viall, NASDTEC Teacher Preparation-Certification Study
Dael Wolfle, Executive Officer, AAAS

It may be noted that the membership has been fairly stable since the presentation of the last report to the NARST. This, in the opinion of your representative, is highly desirable since continuity of effort is needed in order to sustain the long-range activities of the Cooperative Committee.

II. Certification of Teachers of Science and Mathematics

One of the major interests of the Cooperative Committee during the past few

* A report by the NARST Representative on the Cooperative Committee on The Teaching of Science and Mathematics of the AAAS at the Thirty-Fourth Annual Convention of the National Association for Research in Science Teaching at the Pick-Congress Hotel, Chicago, Illinois, February 22, 1961.

years has been teacher certification. The Committee has been involved extensively in all aspects of the problem. One of the major efforts was the development of recommendations for the subject-matter training, which have been published in *School Science and Mathematics* [1] and *Science* [2] and which are commonly referred to as the "Garrett Report." The Committee has also participated in the NASDTEC Teacher Preparation-Certification Study (of which Dr. John R. Mayor is Director, and William P. Viall, Associate Director) and in the activities of the NCTEPS Conferences in Bowling Green, Ohio; Lawrence, Kansas; and San Diego, California.

At the present time the Cooperative Committee has taken its second major step in the development of standards for teacher certification by establishing a sub-committee on Professional Education Requirements. Your representative is Chairman of the sub-committee. Other members are Dr. Harry Lewis; Dr. Seymour Fowler, and Dr. Emery Will. It is expected that the membership may be modified and/or expanded during the coming year when plans for activities are more firmly established.

III. AAAS Feasibility Study

One of the more significant efforts with which the Cooperative Committee is now concerned is the AAAS Feasibility Study supported by the grant from the National Science Foundation. The Study is important in that it represents a move in the direction of examining the program of elementary science and it's articulation with the later programs in the junior and senior high schools. Tentative plans have been established for holding three regional conferences of about forty scientists and educators at which the possibilities of major support from the NSF for the improvement of elementary science will be explored.

Elementary science has not yet received major attention by the NSF and a move in this direction is highly desirable although much caution will be needed. The membership of the NARST is well aware of the different problems that exist between science in the elementary and secondary schools.

IV. Qualifications of Prospective Science Teachers

The next point discussed here is one that involves chiefly your representative and one of another society represented on the Committee. At one of the informal gatherings the representative of the other society stated to the group that (a) he would not allow any of his better science students enter teaching, (b) the ten or so institutions of higher education in the United States *with stature* should train the scientists, whereas the others could train the teachers, and (c) no person with a high-level of ability could be stimulated by the prospect of teaching in a small high school.

Your representative disagreed long and most violently with these premises and continued the contention several months after the meeting. In fact, he proposed that while the right to hold and express such opinions should be staunchly supported by the Committee, the privilege of membership on the Committee should be denied proponents of such beliefs because the basic philosophy of the Committee and its *raison d'être* were completely alien to them. Your representative is firmly convinced that his strong stand and his later refusal to be compromised did much good.

The other issues of note may be found in the minutes of the meeting of the Cooperative Committee distributed to the membership of the NARST at the annual meeting.

[1] Garrett, Alfred B., "Recommendation for the Preparation of High School Teachers of Science and Mathematics—1959," *School Science and Mathematics*, LIX (April 1959), 281–9.

[2] "Preparation of High School Science Teachers," *Science*, CXXXI (April 8, 1960), 1024–29.

ACTIVITIES OF THE AAAS COUNCIL

During the months directly preceding the annual meeting of the AAAS in New York December 26–30, four major Study Committees were established by the AAAS Council. Your representative was appointed to two of these, namely the Committee on Graduate Education and Standards, and the Committee on Science in Secondary School Education. The activities of both of these committees are in the developmental stage. Hence, there is little to report at this time.

In all probability the major topic at the sessions of the AAAS Council dealt with the efforts aimed at obtaining broader participation of the affiliated societies in AAAS affairs. In general, it is difficult to suggest that any major changes or accomplishments were evidenced. However, the relatively nebulous relationships between the affiliated societies and the AAAS and the lack of understanding on the parts of the Council members of their obligations as societal representatives was brought sharply into focus.

Your representative is of the opinion that these "uncovered issues" will provide a solid foundation for future deliberations of the Council. Without doubt they will appear in one form or another, on the agenda of the meeting in Denver in December 1961.

THE NARST RESEARCH SYMPOSIUM

As has been the custom for a number of years, the NARST presented a Research Symposium at the Annual Convention of the AAAS in New York. The Symposium as it appeared in the convention program was as follows:

TUESDAY, DECEMBER 27, 10:00 A.M.: STUYVESANT SUITE

Research Symposium

Arranged by Nathan S. Washton, Queens College

Clarence H. Boeck, President, NARST, Presiding

1. Research and Implications in Teaching Science in the Elementary School. Cyrus W. Barnes, New York University.
2. Research and Implications in Teaching Science in the Secondary School. Hubert M. Evans, Teachers College, Columbia University.
3. Research and Implications in Teaching Science on the College Level. Nathan S. Washton, Queens College.

Unfortunately the time allocated for the meeting was not so satisfactory as in previous years and hence the attendance was less than might have ordinarily been expected. The published report appears in *School Science and Mathematics.*[3]

In general, most persons attending the convention do not arrive until afternoon of the second day, December 27. In the future, this factor might be considered in contemplating the best time for the meeting.

RECOMMENDATIONS

Without question, the activities of the AAAS in which the NARST has participated are of national importance. The wholehearted support of the NARST for these programs and activities should be continued as in the past.

[3] "Problems of Research and Implications of Teaching Science," *School Science and Mathematics,* LXI (November 1961), 595–609.

Official Minutes of the Thirty-Fourth Annual Meeting of the National Association for Research in Science Teaching *

THE PICK-CONGRESS HOTEL
Chicago, Illinois

I. WEDNESDAY, 22 FEBRUARY, 1961

Clarence H. Boeck, twenty-eighth president of the National Association for Research in Science Teaching, opened the annual business meeting at 7:30 P.M. with a brief welcome to the members. Following the approval of the minutes of the 1960 meeting as published in "Science Education," April 1960, he entered upon the "President's Report," which is published in this issue of "Science Education." His report was followed in order by reports from George C. Mallinson, Kenneth E. Anderson, John D. McLain, J. Darrell Barnard, Herman Branson, Joseph Novak, Paul Blackwood, and Ellsworth S. Obourn as recorded in the program of the 34th annual meeting. Item 10 on the program, "Problems Facing the NARST," was given primarily to the problems incident to the republication of the three volumes of Curtiss digests with two volumes of additional material bringing the work up to date. George Mallinson reported that the Western Michigan University Press would publish them with a quarantee of 1,400 five volume packages at $15.00 per package. Fred Meppelink, a graduate student at Western Michigan University, reported on his analysis of 1,200 annotated studies to which he applied NARST criteria. He suggested a format with the titles: Purpose, Data, and Conclusions. Barnard emphasized that two criteria should be kept in mind: 1. The digest should be useful for potential research; 2. The review of research should be of use to the classroom teacher. Possibly only 400 of the 1,200 annotated studies reported can be included in the two volumes according to Mallinson. But Obourn observed that the editor could interpret his role so as to achieve both of Barnard's points. Mallinson, in reply to Smith's question, stated that Curtiss has given permission to reprint the first three volumes. The need for a group to prepare an annual review along the Curtiss lines was mentioned. Mallinson reaffirmed his confidence in the present arrangement with a five man committee and a group to prepare digests. NARST would seek volunteers to review studies. The problem of marketing was introduced by Obourn. Miles commented that 800 sets should go to colleges and universities, another 300 to members, leaving 300 to be sold. NARST could not assume responsibility for disposing of 1,400 volumes, but would help the sale.

In the discussion of problems facing NARST, much attention was given to criteria for membership. The consensus was that the Executive Committee should interpret the eligibility criteria of the bylaws as generously as possible within the best interests of NARST.

President Boeck appointed the Committee on Audit (Hurd, Chairman, Barnes and Weaver) and the Nominating Committee (Bingham, Chairman, Jacobson and Loti).

II. THURSDAY, 23 FEBRUARY, 1961—7:30 P.M.

The committees reported in the order of the program. The Audit Committee (Hurd) found the books of the secretary-treasurer in order. Obourn moved a vote of thanks to the secretary-treasurer. Smith reported the program as published. Miles suggested that the annual luncheon might

* Received by Editor July 27, 1961. No editorial changes made. No other committee or organization reports (except the Cooperative report), nor list of NARST members attending Chicago meeting received.

well be moved to Friday. The desirability of an open evening during the annual meeting was suggested by Oakes. Smith returned with the suggestion that the annual meeting might emphasize buzz sessions and symposia rather than the reading of contributed papers. The excellent printing of the program and luncheon menu was arranged by Boeck. Weiss reported on publicity. He experienced difficulty in securing data from program participants. Three local papers carried generous reports on the Chicago meeting: The Daily News, The Sun-Times, and the Tribune. President Boeck was on radio station WMBT for 5 minutes, 6:00 P.M., February 23, 1961. Fletcher Watson's paper at the luncheon will be covered be the Associated Press and others.

John Read introduced the need for summer workshops in science education. Jacobson observed that summer workshops might emphasize: 1. basic help in philosophy of science (e.g. E. Nagel's work) and the philosophy and design of research. 2. Coordinated research effort. Watson emphasized the need for basic training in modern statistics and the kinds of problems amenable to such techniques. After much vigorous discussion, Herbert Smith concluded on the ever-present need to train people for research in education.

The group then approved the 34 new members recommended by the Executive Committee. The Nominating Committee presented the following slate of officers for 1961–1962:

President........................Herbert Smith
Past President.................Clarence Boeck
Vice President............Ellsworth S. Obourn
Secretary-Treasurer..........Herman Branson
Research Coordinator.......Paul E. Blackwood
Members at Large (Two from the group)
Cyrus W. Barnes, Paul deH. Hurd, Mervin Oakes, Edward Weaver

Novack moved and Colyer seconded that the slate be adopted. There were no nominations from the floor so Glidden moved and Novack seconded that the nominations be closed. Boeck appointed Novak and Colyer as tellers. The first five positions were confirmed; Barnes and Hurd were elected members at large.

Boeck presented the article of incorporation and the by-laws. Myles moved and Weiss seconded that the articles be accepted. Vote was unanimous. Frazer moved and Victor seconded the acceptance of the by-laws. The vote again was unanimous. By common consent the title of Obourn was changed from vice-president to president-elect as stated in the by-laws.

Sipes inquired if NARST was seeking the highest tax exemption status. Boeck replied that the lawyers were at work and that the negotiations would take approximately a year. Watson introduced the idea of international relations for NARST. Boeck reported one informal request from a member for information about NARST to be used in his talks in Europe. Obourn interjected that his counterpart in science education in England visited the United States Office of Education and expressed interest in NARST programs. Obourn emphasized that some international relationships should be of programmatic concern to NARST. Agreed to refer the area to the new president.

The official journal of NARST was discussed in committee of the whole fashion. The group unanimously voted that the Executive Committee undertake negotiations with the owner of "Science Education" to achieve some mutually agreeable modus operandi for the journal; and if these negotiations failed, to sever all official connections with "Science Education" and to explore the possibility of a new journal.

HERMAN A. BRANSON

NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

NARST FOUNDED 1928

This is to certify that

Clarence M. Pruitt

was awarded this citation for

DISTINGUISHED SERVICE IN SCIENCE EDUCATION

by the National Association for Research in Science Teaching

for unselfish, dedicated and outstanding services as a member
and as Secretary-Treasurer of the Association from 19 46 *to 19* 60

In testimony whereof
the President, the Secretary-Treasurer
and other members of the Executive Committee have hereunto
set their hands this Twenty-fifth *day of* February, 19 61

OTHER MEMBERS OF EXECUTIVE COMMITTEE:

Herbert A. Smith

Vaden W. Miles

Ellsworth S. Obourn

Clarence H. Boeck
PRESIDENT

Herman Branson
SECRETARY-TREASURER

NARST Citations

VADEN W. MILES
Wayne State University, Detroit, Michigan

SAMUEL RALPH POWERS

Samuel Ralph Powers, Professor Emeritus and Head of the Department of Natural Science, Teachers College, Columbia University, the National Association for Research in Science Teaching honors you as its first Secretary-Treasurer 1928–1937.

Eminent teacher and director of research; recipient of the OUTSTANDING ACHIEVEMENT AWARD on the occasion of the Centennial of the University of Minnesota, College of Education, in 1951; accorded the SCIENCE EDUCATION RECOGNITION AWARD in 1956; listed in *Who's Who* and *American Men of Science*—your positions and achievements are fully documented for posterity and need not be summarized here. Aspiring scientists and science educators could study with profit and emulate with benefit to future generations this case history of the progression of a keen, penetrating, professional mind as it moved from a rural school in Illinois to positions of great influence nationally and internationally.

Charter member of NARST in 1928, Secretary-Treasurer 1928–1937, President of the Association 1939, chairman of numerous committees, and Editor of *Science Education* 1944 and 1945, you have served the Association with distinction in many capacities. For thirty-three years members of NARST have enjoyed being with you at the annual meetings. Some would characterize your philosophy in these words: Lectures and symposia have their appropriate functions but they cannot take the place of constructive and vigorous debate, in which leading thinkers bring into sharp relief the crucial issues of our day in education and in science education.

For outstanding services and devotion to teaching, to research, and to the Association, the National Association for Research in Science Teaching awards S. Ralph Powers this CITATION FOR DISTINGUISHED SERVICE IN SCIENCE EDUCATION as Secretary-Treasurer of the Association from 1928 to 1937.

ELLSWORTH S. OBOURN

Internationally recognized scholar and science educator; since 1956 Specialist in Science in the Office of Education, United States Department of Health, Education, and Welfare; native of Pennsylvania; awarded the Bachelor of Science degree by Columbia University and the Masters and Doctor of Philosophy by New York University; teacher in the schools of Pennsylvania and New York states; head of the science department in the John Burroughs School in Missouri for more than 30 years; faculty member in the science departments of Columbia University and New York University and at several other institutions including Duke and Northwestern Universities.

In 1951–1952 Dr. Obourn was on a UNESCO mission to Thailand where he served as advisor to the Minister of Education. In 1954 and 1955 he was in

Paris as director of the United Nations Educational, Scientific and Cultural Organization program for science education.

Prolific writer, sound researcher on fundamentals in learning and teaching, vigorous administrator—a man who always shortens the distance between an idea and action. His many contributions to the literature include outstanding research on assumptions and problem-solving in science; eight textbooks used in high school science; a book on the teaching of science; several research monographs from the office of Education; and collaborator on two yearbooks which are landmarks in science education. Dr. Obourn was a member of the committee which prepared the yearbook on *Science Education in American Schools* (1947) and was a contributor to two chapters in the yearbook *Rethinking Science Education* (1960).

An elected and honorary member of many scientific and educational societies of Europe, the Far East, and the United States, Dr. Obourn has served on several national and international committees, has been a director of the National Science Teachers Association, and has held more offices in NARST than any other member.

A charter member of the National Association for Research in Science Teaching founded in 1928, Dr. Obourn served the Association with honor and eminence as its secretary-treasurer from February 23, 1937 to 1945; as vice president in 1947; and as research coordinator from 1959 to 1961. Could any man have contributed more to NARST?

The Association is proud to have him as president-elect for 1961–1962 and president in 1963. The Association honors him with the award of this CITATION FOR DISTINGUISHED SERVICE IN SCIENCE EDUCATION as its Secretary-Treasurer from 1937 to 1945.

CLARENCE H. BOECK

Native son of Minnesota; awarded three degrees by that state's great University of Minnesota; outstanding teacher in its secondary schools beginning in 1935; equally at home on the range as a college professor of chemistry at Oklahoma State University from 1941 to 1947; science educator par excellence recalled to his Alma Mater in 1948 as a worthy successor to the eminent teachers, scholars, and researchers in science education—the late Archer W. Hurd and the late Palmer O. Johnson; currently Professor of Education, University of Minnesota, teaching high school students and graduate and undergraduate methods courses in elementary school science and secondary school science; producer of a definitive research study comparing the inductive with the deductive method of teaching chemistry; author of numerous articles published in magazines devoted to research in education and the teaching of science; co-author of a forthcoming chapter in the *Review of Educational Research;* engaged in research on the use of closed-circuit T-V and kinescopes; member of many professional organizations who first attended and presented a paper at the Silver Anniversary Meeting of the National Association for Research in Science Teaching in 1952; chairman or co-chairman of the NARST Review Committees for the Third, Fourth and Sixth Annual Reviews of Research in Science Teaching. For all of these accomplishments, and for your service and devotion to teaching, to research, and to the Association, the National Association for Research in Science Teaching honors you, its vice-president in 1959–60 and president in 1960–61, with this CITATION FOR DISTINGUISHED SERVICE IN SCIENCE EDUCATION.

CLARENCE M. PRUITT

The mark of the immature man is that he wants to die nobly for a cause, while the mark of the mature man is that he wants to live humbly for a cause. Clarence Martin Pruitt has in his modest, quiet manner markedly advanced the cause of science teaching, teacher education, and research in science education with his unique abilities and relentless effort since he first stepped into the classroom of a rural school in his native Hoosierland in 1915. His sincere human qualities and dedication to science education have won the respect and admiration of all of us.

Dr. Pruitt's colleagues in research judged three of his research investigations of superior quality for inclusion in the Curtis' Digests of Investigations in the Teaching of Science. His pioneering research on subject-matter concepts and generalizations in chemistry has stood the test of time and is recognized as a milestone in science education. The Council of Elementary Science International has recognized his publications and contributions to that field by electing him to its Board of Directors for several years. The breadth and depth of his training and interests range from kindergarten through the graduate school. His services have been in great demand for he has been on the faculties of New York University, the University of Illinois, Colorado State College of Education, Oklahoma State University, the University of Tampa, and the summer session staffs of several other institutions.

Member of the National Association for Research in Science Teaching since 1929 and longtime life member (1933); business manager of the Science Education in the nineteen thirties; editor since 1946 of the Association's official journal, *Science Education;* awarded a citation by NARST in 1958 for three decades of Meritorius Service; elected as the Association's first honorary president in 1960; the National Association for Research in Science Teaching again honors you with the award of this CITATION FOR DISTINGUISHED SERVICE IN SCIENCE EDUCATION as secretary-treasurer of the Association from 1945 to 1960.

June 1, 1961

Dr. Herbert A. Smith
University of Kansas
Lawrence, Kansas
Dear Herb:

This morning I talked at some length with Clarence Pruitt regarding the possibility of negotiating an arrangement whereby NARST might obtain effective control of *Science Education*. This is a summary of our conversation:

1. He feels that dissatisfaction with *Science Education* is not an attitude shared by a majority of the membership of NARST, but limited to a few members some of whom he named. I explained that the action to do something about NARST's relation to *Science Education* was taken by members during its annual business meeting. He stated that, as a member of NARST, he is planning to survey the opinion of NARST members. He said he wanted members to get his side of the story. When I pointed out that this would represent a biased survey, he seemed not to feel that it would.

2. He stated emphatically that he wanted no part of a proposition whereby NARST would assume editorial control and policy determination for *Science Education* at this time. He said he might consider the proposition some four or five years from now. Mrs. Pruitt said they found it difficult to understand why there was dissatisfaction with *Science Education* since they receive no letters that are critical of the JOURNAL. She, too, felt that this was a reaction of only a few members of NARST.

3. He stated that the reason for not answering my letter of April 10 was that such a face-to-face meeting with him as proposed in the letter would be useless. He repeated again that he had no intention of changing his position as set forth in the April issue of *Science Education*.

4. When I asked him about an outright sale of the JOURNAL, he replied that many things could be bought for a price. When I asked what price he would set, he replied that it would be of an order which NARST could not possibly afford to pay. He wanted to make it clear that his interest in the JOURNAL is not a mercenary one; that he hardly more than breaks even on it.

5. When I told him, that in the light of his unwillingness to consider the proposition, NARST will begin immediately to explore other publication outlets and will in all probability sever relations with *Science Education* he replied that this he would regret but did not intend to change his present position in the matter.

6. He also stated he had turned over all pertinent records to Dr. Branson. He stated that his record book on past payment of dues was not in his judgment of any present importance to NARST.

I told Clarence that I intended to write to you about our conversation and that I would send him a copy of my letter.

Sincerely yours
J. DARRELL BARNARD
Chairman

IN MEMORIAM

NARST—SCIENCE EDUCATION

MAY 1929—DECEMBER 1961

June 26, 1961

Dr. Clarence M. Pruitt
Editor and Publisher, Science Education
University of Tampa
Tampa, Florida

Dear Dr. Pruitt:

At the direction of the Executive Committee of the National Association for Research in Science Teaching it becomes my unpleasant duty to convey to you information about a recent official action which the Executive Committee took on June 24, 1961 in a called meeting at Washington, D. C. It was their unanimous decision to sever the relationship between the NARST and *Science Education* effective as the end of the Annual Business Meeting in February, 1962. Payment of the agreed upon $8 per dues-paying member for the JOURNAL will terminate upon payment of this sum for the year 1961. We request that any reference to NARST be removed from the masthead of *Science Education* following the last issue of the JOURNAL in the calendar year 1961.

The Executive Committee did not reach this decision arbitrarily or capriciously, and have taken this step only after all reasonable alternatives seem to have been exhausted. In view of a mandate from the general membership at the last annual meeting on February 23, 1961 that a satisfactory resolution of the problems involved be reached, or that the existing relationship between NARST and *Science Education* be dissolved; and further, in view of the summary of the discussion which you had with Dr. Barnard, who was acting for and in the name of NARST, the Executive Committee believed that it had no recourse but to take this action.

The Committee is most appreciative of your years of service and dedication and they are cognizant of the long years of fruitful association between NARST and *Science Education*. They can also understand your desire to maintain the status quo and your right to insist that long established customs remain unchanged. But effective cooperation involves at least two parties. You are well aware that there have been certain dissatisfactions from time to time and perhaps some of these have been picayune and petty. Perhaps most fundamentally, however, there has been a growing conviction among the membership of the validity of the principle that the official organ of an Association ought to be under the effective control, in editorial and policy matters, of the Organization. It was on this principle that the Executive Committee felt that it could no longer compromise.

Although I must bear a full share of the responsibility for the decision made, I want to assure you that I refused to be pushed into any precipitous decision in spite of the urging for speedy action from several quarters. Only when I became convinced that all avenues for an agreeable compromise had been exhausted, did I permit such a decision to be considered.

Sincerely yours
HERBERT A. SMITH
President

EXECUTIVE COMMITTEE MEMBERS

HERBERT A. SMITH, 1962
ELLSWORTH S. OBOURN, 1962
HERMAN BRANSON, 1962
CLARENCE H. BOECK, 1962
PAUL E. BLACKWOOD, 1962
CYRUS W. BARNES, 1962
PAUL DEH. HURD, 1962
VADEN W. MILES, 1961
EDWARD K. WEAVER, 1961

MEMORANDA TO NARST MEMBERS

Member, NARST

Dear Colleague:

At the last annual business meeting of the Association the Executive Committee was instructed to seek an arrangement whereby effective policy and editorial control of SCIENCE EDUCATION would be transferred to the NARST. In the event that such efforts were unsuccessful, the existing relation between SCIENCE EDUCATION and NARST was to be terminated and other avenues for the publication of Association records and proceedings were to be explored.

Subsequent negotiations to carry out the mandate of the membership with respect to acquiring control of SCIENCE EDUCATION have been unsuccessful. As a result, the Executive Committee met in Washington, D. C. on June 24, 1961 and took the following action:

It was moved that:

The relationship between SCIENCE EDUCATION and NARST be severed as of the end of the Annual Business meeting in February, 1962.

The motion passed unanimously.

HERBERT A. SMITH
President, NARST

University of Tampa
Tampa, Florida
April 30, 1961

Members of NARST:

Regretfully this memorandum is addressed to all members of the National Association for Research in Science Teaching. Its purpose is to inform many, if not most, of you in regard to a very important matter relating to NARST and its official publication *Science Education.* An expression of the opinion of each NARST member is being solicited.

Since this request is coming from the only paid and greatest length of time Life-Member, a member of the first-elected group to NARST, an active member of NARST since 1929, and also the Editor of *Science Education,* and is outside the aegis of official sanction of NARST itself or its Executive Committee, the solicitation may be characterized as completely unofficial. However as a member of NARST and as Editor of *Science Education,* we believe it is definitely within our right, privilege, duty, and our great responsibility to bring a certain matter to your attention and ask each of you for an expression of your opinion or desires.

Some may consider silence on our part would be the better part of valor, but we think now is the time to be vigilant, if we are not to lose our identity but preserve our freedom and integrity.

Briefly, and possibly bluntly, you are asked to express your opinion as to whether NARST shall initiate a new magazine as its official publication (or make arrangements to control cooperatively another existing professional magazine in the teaching of science) or continue to use *Science Education* as its official journal.

Recently there seems to have developed in NARST a group that has become increasingly restive regarding both the Secretary-Treasurer position in NARST and also NARST's relations with *Science Education.* Personally, we do not know the membership of this group nor its exact extent. Since its activities have manifested itself primarily at the last two Chicago meetings, we shall, for lack of a possibly better definitive name, call this group *The Chicago Group.* Correspondents to the writer have called this group the Empire Builders, the New England Group, the Washington Group, and so on. We prefer the name *The Chicago Group,* although we doubt very much that any Chicago NARST are among its members: (Wilbur L. Beauchamp, Muriel Beuschlein, John C. Mayfield, or Bertha M. Parker).

Recently (both 1960 and 1961) matters of vital concern to all members of NARST have been decided by a minority group of NARST members meeting at the time of the annual meeting. We feel that such decisions as the one in 1960 should have been made only after *all* sides of the issue had been presented and that the person vitally concerned in the decision and its effect upon *Science Education,* had been mutually and personally consulted. As it was, the decision was made a Coup d'État! Seemingly now a far more important decision is to be made in exactly the same manner with NARST members at large again not to be consulted—a second Coup d'État, since the first was so successful! We are asking you for an Expression of *Your Opinion* with the hope that the NARST Executive Committee and the members present at the 1962 annual meeting will be greatly influenced and guided by your Expression.

The expression of opinion we are asking you to make is one of the most im-

portant, if not the most important, that members of NARST have ever been called upon to make in the history of the organization. This includes the decision to organize NARST in the first place, the decision to make *Science Education* the official publication of NARST, and the decision to admit Negroes to membership. This is your *One Chance* to express your opinion.

Science Education has been or is to be presented with what amounts to an *Ultimatum.* This term has not been used but in essence that is what it is. Absolute control of *Science Education* is sought, if not at once, then in a very short period of time. If *Science Education* is not handed over relatively soon, then the Chicago Group proposes to initiate "a new elite magazine" of its own or a much more remote possibility to purchase and/or cooperatively control another existing professional science teacher magazine.

It is quite possible that one or two, or even all members of the Executive Committee are not members of what we have designated as The Chicago Group. Possibly the action of the Executive Committee may be entirely directive and is based upon voted directives taken at the 1961 Chicago meeting and in no way represents the Executive Committee's views either individually or collectively. We do question the *Authority* of the Chicago Group or even the Executive Committee to speak for all NARST members or to take such a decisive action as presumably contemplated without affirmation of all NARST members.

In a letter to the Editor of *Science Education,* Dr. J. Darrell Barnard, President of the National Science Teachers Association, wrote as follows. (Presumably Dr. Barnard represents or is speaking for the Executive Committee of NARST, but in no case does he say this either directly or by implication. In view of his NSTA position, he could imaginably be acting for both NARST and NSTA. One rumor that has drifted down to us is that the assigning of control of *Science Education* would be a first step in its final merger with *The Science Teacher.*)

New York University
School of Education
Washington Square
New York 3, New York
April 10, 1961

Dr. Clarence M. Pruitt
University of Tampa
Tampa, Florida

Dear Clarence:

I would like to meet with you in Florida at your convenience to see if you and I can work out a plan whereby NARST's interest and your interest in Science Education might be met in a mutually satisfactory manner.

As you may have heard, there has been a proposal that NARST strike out on its own in publishing a new journal. (Italics ours) To those of us who learned to think of Science Education as the one and only professional journal in science education this would be a sad event.

You know that many of us greatly appreciate the fine service which you have provided over the years in publishing Science Education. Few of the younger members of NARST understand how you have struggled through difficult times to preserve this fine journal. I feel strongly that your interests and personal feelings should be given primary consideration in *whatever decisions the Executive Committee of NARST make with regard to its official journal.* (Italics ours).

If the idea of my spending a day or so with you meets with your approval, what dates between now and June 1 would be most convenient for you?

Respectfully,
Darrell

J. Darrell Barnard
Chairman.

Note that the *final decision* of NARST as to its official journal seemingly is to be made by the Executive Committee only—not even subject to approval by members present at the annual meeting, let alone all members of NARST!!! A Coup d'État for members, too!!

Some newer members of NARST possibly need a briefing on the history of NARST and *Science Education.* (They will find this in some detail in the Silver Anniversary Number of the National Association for Research in Science Teaching published in the February 1953 number of *Science Education*).

Historically NARST was organized at a Boston meeting in 1928. At that time there were three professional magazines in existence: *School Science and Mathematics,* sponsored by the Central Association of Science and Mathematics Teachers; *Journal of Chemical Education,* sponsored by the American Chemical Society; and *General Science Quarterly,* unsponsored and published by the late Walter G. Whitman. Negotiations were soon initiated by the newly organized NARST group to use the *General Science Quarterly* as the official publication of NARST and the name of *General Science Quarterly* was changed to *Science Education* with the May, 1929 number. In 1931 Walter G. Whitman sold his interest in *Science Education* to a group which formed Science Education, Incorporated. Mr. Whitman remained as one of the original stockholders which also included NARST, Charles J. Pieper, Gerald S. Craig, Florence G. Billig, Earl R. Glenn, and Clarence M. Pruitt. Professor Charles J. Pieper of New York University became the Editor of *Science Education* with Earl R. Glenn as Business Manager and Clarence M. Pruitt as Book Review and Abstract Editor. Following a precarious financial situation in 1933, Clarence M. Pruitt became Business Manager. Eventually all of the outstanding stock of *Science Education* was purchased by Clarence M. Pruitt.

World War II was a period of great stress and strain for both NARST and *Science Education* and in the fall of 1945 we became Secretary-Treasurer of NARST and also Editor of *Science Education* beginning with the first issue of 1946. Both tasks were initially assumed with the greatest reluctance. The exigencies of the World War II period passed and both NARST and *Science Education* emerged into a period of relative stability. One of the main tenets of Professor Pieper's editorship was that *Science Education* should not become the mouth-piece or follow the party-line of any institution, organization, or person. That has been our ideal, too, through the years. *Science Education* has scrupulously avoided any tendency toward indoctrination of any sort or to advance personally or professionally the person serving as its Editor. Writers in *Science Education* always have had absolute freedom to say what they please, secure in the assurance that anything they said would not be deleted, should it not conform to the Editor's own particular philosophy of science education. Incidentally it might be added again that no one connected in any way with publishing *Science Education* has ever received a penny of compensation for his work. All service has been gratis.

The exact nature of the criticisms of *Science Education* has never been precisely spelled out to the Editor. As we said in the April 1960 article "For the Record," the criticisms, in part, probably relate to the content of the articles, the editing of same, the *Science Education* Recognition awards, and possibly everything in general. At the 1960 Chicago meeting of NARST, the Editor agreed to having an NARST Editorial Committee *Screen and Edit* all future NARST materials that appear in *Science Education*—effective after the 1960 Chicago meeting. This Editorial Committee was to obtain all NARST papers, etc., edit same, and

present same to the Editor ready for publication in *Science Education*. This procedure seemingly met the first two criticisms listed above. Up to date, we have received possibly half of the material relating to the 1961 Chicago meeting.

As to criticism relative to the content and quality of articles published, there is not too much that the Editor can do here, except to use the best articles available. It is possibly true, that in general, articles today do not quite reach the quality of earlier articles. This despite the fact that many of the more recent articles (as compared with earlier articles) have been wholly or in part subsidized. Subsidization, in general, does not seem to have improved the quality of articles being written. We doubt that recent writers, on the whole, (the last decade and a half) have authored as incisive, influential, and investigative writings and texts as did writers in the earlier period: Francis D. Curtis, S. Ralph Powers, Gerald S. Craig, Florence G. Billig, Hanor A. Webb, E. Laurence Palmer, Ralph K. Watkins, Harry A. Cunningham, Morris Meister, Martin Robertson, Earl R. Glenn, Elwood D. Heiss, Benj. C. Gruenberg, Ira Davis, Wilbur Beauchamp, N. Eldred Bingham, H. Emmett Brown, Lillian H. Darnell, Lois M. Shoemaker, Katherine E. Hill, Victor H. Noll, Charles J. Pieper, Louis Thiele, Mervin E. Oakes, Bertha M. Parker, Ralph Tyler, George Wood, James C. Adell, Palmer O. Johnson, J. O. Frank, Elliott R. Downing, Otis W. Caldwell, George Haupt, W. L. Eikenberry, O. E. Underhill, Ralph Horton, Archer W. Hurd, Joe Young West, Charles Finley, George Hunter, Harry A. Carpenter, Walter G. Whitman, Glenn O. Blough, Robert K. Wickware, Frank C. Jean, Ellis Haworth, W. A. Kilgore, Herbert S. Zim, Clark Hubler, Julian Greenlee, Nathan Neal, Arthur Baker, Greta Oppe, Leona Sundquist, F. A. Riedel, and possibly others. Some of the above listed names naturally lapse over into the last decade and a half and other modern writers of note such as Betty Lockwood Wheeler, Kenneth E. Anderson, W. W. E. Blanchet, Rose Lammel, Jerome Metzner, William B. Reiner, Hubert M. Evans, George G. Mallinson, Wm. C. Van Deventer, Phillip G. Johnson, John S. Richardson, and others, extend back into the earlier period. Many fine papers have been published in the last decade and a half, possibly equalling in quality the very best papers of the earlier period. Unfortunately a number of more recent papers have not lived up to their potentialities, especially considering the fact that more recent writers have been able to build upon the earlier techniques, and could profit by the shortcomings of their predecessors. Better evaluative and statistical techniques are available also to present-day writers. While research in science teaching has declined or almost entirely disappeared from such earlier centers as the University of Chicago and the University of Michigan, their places have been taken by noted research coming out of the University of Kansas and Michigan State University. A number of institutions such as Teachers College and New York University and others have always been and still are centers of important research activities.

It is agreed that some articles appearing in *Science Education* on occasions could have been changed for the better or possibly should have been omitted altogether. In many instances when changes have been made to what we thought was a better word or phrase, the author has not agreed—he meant what he said in the first place! We do not consider our task as Editor to rewrite or emasculate an article in such a fashion that the author can scarcely recognize his earlier writing. We personally prefer to make as few changes as necessary and to have the author's own literary style be in evidence. After all, many of our writers are doctoral recipients and are individuals well known in the educational world.

Naturally all articles are not equally good. We have published a few (?) papers from even NARST members we have definitely considered sub-par, but which the said member considered pretty good. Our own brain-children look pretty good to us, albeit they appear to be little "brats" or research and/or literary monstrosities, to some readers. Some of these "brats" seem so unique or important to their author, that the author seems to believe that great harm will be done or the reading world will be seriously handicapped if they are not published in the next issue or at least the following issue. As Editor of *Science Education* we have always been receptive to better articles and if such articles are known by NARST members to be available for publication, they should appraise the Editor of this fact. Workers in the field are remiss in their obligations to the science teaching field if they do not suggest to the potential author the importance his writing up the material and submitting it for publication. Editors are often vainly seeking these elite, unpublished articles! To our own personal knowledge, we have never turned down one such article in our sixteen years as Editor of *Science Education*.

Individuals who have received Science Education Recognition Awards have seemed most grateful and highly pleased in all instances so far as we know. At least, practically all of them have ordered reprints of the write-up! Our policy has been, in general to use, older deserving members of the science education teaching profession. However, we are always open to nominations or suggestions, and if you feel some person has been neglected, please write us.

Granted that there has been failures on our part to carry out our tasks at summit level as Editor of *Science Education* we could cite equally or even greater failures on the part of NARST to live up to its obligations, and responsibilities to *Science Education*.

Earlier we said we feel reasonably certain a second Coup d'État would have been our fate at the 1961 Chicago meeting had we not owned *Science Education* and been in a position to personally decide the immediate future status of the magazine. Our assurance in "For the Record" as to the future of *Science Education* seems to have only whetted some appetites for greater immediate control. A year ago an Editorial Committee control seemed to satisfy completely. Now seemingly much more is desired. Presumably a year from now nothing short of absolute control will satisfy. In lieu of this—a new magazine is the only alternative!

We do not believe that this viewpoint and proposed policy represents the desires or wishes of most members of NARST. We believe the desire of all members of NARST is the same as ours has always been—to best serve the principles and interests of NARST and *Science Education* and not to render asunder. Fundamentally, devoid of all attempts that may or have been made to becloud the issue, the question is: Do you want a new magazine to officially represent NARST or shall *Science Education*, as it has for the past 33 years, continue to be the official NARST publication?

Science Education over the years has performed a unique and important function as a science education publication. It is our intention to presently carry on as we have been doing. That is the least we can, in honor, do. We too, have obligations and responsibilities to many loyal supporters, NARST members, readers, and friends: We *Are Not* about to turn *Science Education* over to any group or individual. This is our considered decision. For our part we stand on what we said in "For the Record" and in the 1960 agreement with NARST relating to an NARST Editorial Committee.

Admittedly *Science Education* would be hurt financially, prestige-wise, and so on, should NARST decide to use a new or another magazine as its official journal. We would hope that an NARST decision to not officially sponsor *Science Education* would not be fatal to *Science Education.*

The handicap would be immeasurably greater than the one imposed by the earlier 1960 decision.

We urge and challenge all members of NARST to express their opinion in the forms at the end of this memorandum. While your expressed opinion is, even if favorable to *Science Education,* not binding upon the Executive Committee of NARST nor upon the members attending the 1962 annual meeting, the expression of your desires could be and should be a very decisive mandate. This is probably the *One* and only opportunity for most of you to indicate his desire. Have the *Courage* and *Intellectual Stamina* to exercise your NARST right and obligation! All *life* members also are urged to vote. Possibly of all members, theirs is the greatest responsibility! Return your ballots *at once—Now* before you forget it.

The Editor naturally would appreciate your comments in relation to the above, to all phases of *Science Education,* and on the decision we have made. Write us!

So that there will be no question as to the final tally of the expression of your opinion, we are asking that you in fairness to the Executive Committee, NARST itself, and to *Science Education* mail two coupons. The need for this should be readily apparent to you! One coupon to

Dr. Herbert A. Smith, President
National Association for Research In Science Teaching
University of Kansas
Lawrence, Kansas

and one coupon to

Dr. Clarence M. Pruitt, Editor
Science Education
University of Tampa
Tampa, Florida.

Please mark both coupons in exactly the same manner! We also urge you to sign your name to each coupon. We believe each member of NARST has so much at stake that he should stand up gladly and be counted!

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ULTIMATUM: BETRAYAL OF A LOYALTY

Clarence M. Pruitt

Some of you may little note and less care what we may say here regarding the NARST decision. A few will consider any explanation made by *Science Education* as being highly biased and unethical as has been suggested to us. Be that as it may, an explanation from the viewpoint of *Science Education* would seem to be in order for most members of NARST and for *Science Education* non-NARST readers. Such an explanation is also due the future readers of *Science Education* or historical investigators of present science education status, as they will appraise it as the Twenty-First Century emerges.

One does not have much of a choice when one is confronted with an ultimatum: Accept or Reject. This was our status in regard to NARST and *Science Education*. No real basis for either negotiation or compromise was manifest. We were asked to hand over *Science Education*, lock, stock, and barrel, about as nonchalantly as you may shift to read the next page. In our June 1 telephone talk with Dr. Barnard, we pointed out that NARST had requested and that *Science Education* had granted NARST the right to *obtain, determine, and edit* all NARST material appearing in *Science Education*. (See April 1960 *Science Education*.). At the 1960 meeting this agreement seemed to completely satisfy NARST and it was understood that an Editorial Committee of NARST would collect and edit all subsequent NARST materials to appear in *Science Education*. It was also agreed that Kenneth E. Anderson and committee would mimeograph subsequent NARST papers for distribution at the annual meeting. *Science Education* readily agreed to this proposal, also. These concessions seemingly did not at all satisfy a few NARST members. Dr. Barnard made this attitude quite plain to us. When we offered to CONSULT with any Editorial Committee of NARST on ALL other aspects of the publication of *Science Education*, Dr. Barnard replied that he did not believe such consultation would be at all satisfactory to NARST. (This belief was later confirmed at the Executive Committee at Washington, D. C. June 24.) The only thing that would satisfy NARST would be for us to turn over *Science Education* completely to NARST. This we firmly declined to do. We then felt, and still do, that we had made the ultimate possible concession to NARST in matters relating to *Science Education*. It was quite evident that the NARST representatives were not at all interested in any compromise.

While Dr. Barnard mentions the purchasing of *Science Education*, there was no indication of any serious offer. The conversation along this line lasted possibly a minute—certainly less than two minutes. It was more in a bantering manner, as someone might say on meeting an old acquaintance: "That's a nice suit you have on. How much would you take for it?" And the second person in a similar mood says "You couldn't buy it for a million dollars." You will note that nothing about a possible purchasing of *Science Education* is mentioned, or even hinted in the Official Minutes, nor in Barnard's April 10 letter, nor in Smith's letter of June 26, or in any other communications with the writer.

It is altogether possible that NARST representatives very well knew, and even hoped, that our answer would be *No*. There is no evidence that they were in any mood for compromise. A firm *No*, as they should have rightfully expected, would clear the path for what was intended in the first place—a new publication to be used for certain specifically planned purposes.

We would raise the question as to whether all members present at the Annual Business Meeting on February 23, 1961 and voting "Unanimously" really understood what they were voting for: That *Science Education* be turned over completely and at once to NARST and that in case it was not, that NARST was to start a publication of its own. This despite the fact that the Official Minutes do so definitely state. Did the members present and discussing this motion, understand its full import, and so vote? We were not present so have no firsthand information, nor has any NARST member present at the Business Meeting written us to this effect. It seems a little strange to us that NARST members then present could seriously ask and *Unanimously* vote that a magazine not owned by NARST but which had been utilized as their service publication for 33 years, and first paid for financially by a group of NARST members and NARST itself, should be immediately turned over to NARST—or *Else*—the Else being the starting of a new publication. Possibly so! It's a strange world!

We had definitely planned to send to each member of NARST the April 30 brochure (see pages 465–471) presenting the *Science Education* side of the issue, since no one was present officially to defend *Science Education* at the Annual Business Meeting nor before the Executive Committee. Even if the brochure were biased as has been suggested, we personally doubt that NARST members would be so naive as to consider that aspect as greatly favoring *Science Education* over NARST. The action of the June 24 Executive Committee meeting put a final quietus upon the once contemplated earlier plan. It is published in this issue more as a part of the record and for the information of more recently elected NARST members.

Some may possibly question our right and the ethics of presenting the side of *Science Education* as is now being done. At least some individuals may be somewhat put out.

Why were not All members of NARST afforded the opportunity to vote on the question of continuing *Science Education* as the official publication of NARST? Were some members very much afraid of what the outcome might be? Why no annual financial statement this year or list of members attending? Why the paucity of Official Minutes despite the more than usual important matters discussed in lengthy Executive Committee Meetings and the supremely important Business Meeting? Why not a list of names of NARST members voting to initiate a new publication and those opposed (even if Official Minutes state there were none opposed)? Why were not *All* NARST members notified before the Annual Meeting that the most important issue ever to be considered at an Annual Meeting was to be decided at the 1961 Business Meeting? Are the discussions held and the decisions made at the annual meeting both in Executive Committee and at the Business Meeting to be more and more secretive? We raise these questions as the only paid Life Member and with the exception of Charter members, a member whose length of membership exceeds all members except possibly two or three members.

Although assured that 80 per cent or so NARST members are dissatisfied with *Science Education* as the official publication of NARST, we find this very difficult, if not impossible to believe. If the per cent of NARSTers dissatisfied with continuing *Science Education* as their official publication, were as great as suggested, it would seem NARST would have actually welcomed such a concrete manifestation of its position and thus give us our proper come-uppance! NARST on the face of such alleged overwhelming dissatisfaction with *Science Education* should have been the first to suggest an expression of opinion long before we were aware that such a condition existed! We believe that

the reverse is actually true! It is our conviction that had the issues been fully presented to *All* members of NARST, that *Science Education* would have received affirmation by more than 80 per cent—even 90 per cent—of NARST members.

The fact is that not *One* member of NARST (nor anyone else) has written to us suggesting any major or minor dissatisfaction with *Science Education* during our sixteen years as Editor. Some authors have, at times, asked us to speed up the publication of their article, for one reason or another. Usually we have complied with these requests. (We do not consider this as really showing dissatisfaction with *Science Education.*)

On the contrary, many NARST members have, at one time or another, been quite complimentary about *Science Education.* Within the last year more or less, three of the half dozen most outstanding members of NARST have written us very nice and appreciated letters about *Science Education.* Three authors in the October issue took time to compliment us upon the handling of their article. A Dean of a college as recently as two weeks ago (September 1) told us he was very pleased with the April issue and said "Keep up the good work." On the other hand, if the criticisms are as extensive as has been alleged, maybe we should be most thankful and appreciative of NARST members who have refrained from expressing their real feelings to us.

Our motive in retaining control of *Science Education* is decidedly not a mercenary one. Our many years of free service attest to that—years that conceivably could have been devoted to tasks and writings more remunerative financially. On the other hand we have had no thought or feeling of posing as a martyr or as a hero. The choice on our part was freely made. Nor have we ever used *Science Education* for personal glorification or self-advancement, or professional advancement in the college in which we have taught. As a matter of fact, we have always played down this phase of our activity.

We do not question the legal right and the freedom of NARST or any group or any individual to start a new magazine of their own. That is an American heritage of long standing. In the case of NARST and *Science Education* we do submit that there may be a moral and ethical question involved. There may be a number of reasons for starting new publications such as:

1. No magazine in existence now performs the services needed.

2. Other magazines are so tied up with other organizations that they cannot perform the needed services.

3. Much material meriting publication cannot now be published in any magazine because of lack of space.

4. Present magazines do not have sufficiently high standards as to materials included, and so on. Hence there is a real need for a more elite, sophisticated publication.

5. Financial return to the new group or individuals publishing a new magazine.

6. Personal and prestige ambitions of persons desiring such an outlet.

7. Indoctrination and/or propaganda—to put across, foster, and emphasize certain beliefs, purposes, doctrines, and so on not now being emphasized in existing publications.

8. . . .

It may well be that all of these purposes, parts of the same or others not mentioned, are reasons for starting a new NARST publication or the newly proposed *Journal for High School Physics Teachers.* Three new professional magazines may break the gates in 1962. Maybe the more, the merrier! The competition promises to be keen in more ways than one!

Dr. Smith in his letter says "there has been a growing conviction among the membership of the validity of the principle that the official organ of an Association ought to be under the effective control in editorial

and policy matters of the Organization." Exactly what does this mean? The same control (voice) that non-present NARST members at the Chicago meeting (which was a vast majority of all NARST members) had in deciding whether *Science Education* was to continue as the official organ of NARST—which was no voice at all! Even the suggestion of giving a voice to all members (especially to all members unable to attend the Annual Business Meeting) has been questioned. Whose and what policies, propaganda, and/or indoctrination does the new magazine plan to promote? Manifestly the Editor or a small group must make the decisions. Is the new Editor to serve as the mouthpiece of an Editorial Committee or an Executive Committee, who may serve as a sort of Board of Censors to see that the new magazine pursues the proper propaganda line? Or will the new Editor be kicked out, in a manner of speaking as we have been, if he strays too far away from the planned purposes? It will be vigorously, vehemently, hotly denied that any such purpose is in mind. Do most members of NARST desire such a policy publication, even if it is not a propaganda line? Or do they prefer the policy pursued over the years by *Science Education*—as a non-party line, non-indoctrination, non-propagandized publication—for any individual, group, organization, or college?

In "For the Record" we are on record as desiring to ultimately transfer *Science Education* to NARST and CESI cooperatively. But that time is not now nor in the future as events have determined. In a letter available to Mrs. Pruitt (since destroyed) we had designated a noted NARST leader to assume temporarily the duties of Editor of *Science Education* in case of any emergency in our being unable to function as Editor.

The decision to end publication relations between NARST and *Science Education* was made by NARST—not by *Science Education*. This decision severs relationships that have covered almost a professional life time—33 years—beginning May, 1929 and ending December, 1961. The NARST decision involves a future that presumably goes beyond the life-time of all present NARST members. Yet this most important decision in all of NARST's existence was not considered of enough concern or sufficient importance to be brought officially to the attention of *All* members of NARST before the decision was made and only a relatively few members had any part in it.

The members of NARST as a whole may still have it within their power by swift, affirmative action to rescind the decision made by the Executive Committee. It could well be also that the holocaust of a nuclear war might negate the need for a magazine of any kind!

Personally we are more saddened, anguished, keenly disappointed, flabbergasted, than angered. Through the years as a member of NARST (1929), as a Life-member (the only paid Life-member) for 28 years, as Secretary-Treasurer for 16 years (1945–1960) and in connection with *Science Education* for 30 years (1931–1961), Book Review Editor, Circulation Manager, Business Manager, and as Editor for 16 years, we have always worked to promote the best interests of NARST, always to unify, never to render asunder NARST by word or deed. In at least one respect we humbly believe that no member's loyalty to NARST has exceeded our own. Of course, we readily admit that this is our own characterization of ourself and could be biased! Certainly there are a number of members whose loyalty over many years has equalled ours—Craig, Powers, Webb, Billig, Wheeler, Curtis, Palmer, Cunningham, Grüenberg, Glenn, Adell, Baker, Baer, Pieper, Brown, Blough, Darnell, Evans, Heiss, Hill, Jean, Metzner, Meister, Reiner, Raskin, Robertson, Shoemaker, Sundquist and many others. Nor do we make any claim that we have done the most for NARST. That

distinction, we believe, should go to Dr. Samuel Ralph Powers. There are others who are not far behind.

Pleasant relationships that have existed in the past between NARST and *Science Education* involve loyalties that are not easily cast aside. As *Science Education* bids farewell to NARST as its official publication, we want to take this opportunity to assure all members of NARST that their loyalty, cooperation, friendship, and good will through the years have been very much appreciated. Whatever small contribution that *Science Education* may have made in improving the teaching of science in American schools has been largely that of cooperative, loyal members of NARST. As Editor we have served largely as a service medium. Patience in many ways has been much in evidence—both by NARST and by *Science Education*. NARSTers have been most patient when *Science Education* has been late in publication or your articles have not been published as rapidly as you would have liked. For *Science Education* it may be said that many of you were often tardy in paying your NARST dues and hence *Science Education*—not that we were greatly put out by this tardiness! Thus *Science Education* carried you when you were in arrears. Some of you at a given time were always in arrears. With patience and understanding on our part, you always came through! Negligence was almost the sole reason for being in arrears. As of this date (November 16, 1961) only 116 of you are paid up for 1961, yet *Science Education* has carried you through the year. All of this is mentioned to offer concrete evidence that *Science Education* has been patient, too! Other instances of minor irritations on both sides could be cited, of course.

We do beseech from as many of you as will your continued loyal support, your sympathetic understanding for carrying on of *Science Education* in the years that lie ahead. Needless to say your active support, articles and otherwise, will now be needed more than ever, albeit it has been extremely important in the past. Through the years we came to know most NARST members (except in the last two years) personally. We have prized this acquaintance and friendship beyond our ability to adequately express. Any points of controversy, past or present, are not to be considered as being of a personal nature. Some of our longest and closest friendships exist with members of the Executive Committee.

We think that *Science Education* in its 33 years relationship with NARST went the Second Mile.

Julius Caesar some two thousand years ago rather aptly summarized our feelings in his famous (infamous for many a high school sophomore) fourteenth Chapter "That less of hesitation was given to those things which the Helvetian embassy had mentioned because he bore it the more grievously the less deservedly it had happened to the Roman people, who if they had been conscious of it, it would not have been difficult to have avoided it."

But as the Rubáiyát of Omar Khayyám said long ago:

> The Moving Finger writes, and, having writ,
> Moves on: Nor all your piety nor wit shall lure
> it back to cancel half a line
> Nor all your tears wash out a word of it.

The responsibility for all of the above is ours alone. No other person has been consulted personally or by correspondence.

With the close of the next sentence, the position of *Science Education* as the official publication of NARST ceases—and a noted NARST—*Science Education* relationship comes to an end.

Your letters and comments will be appreciated.

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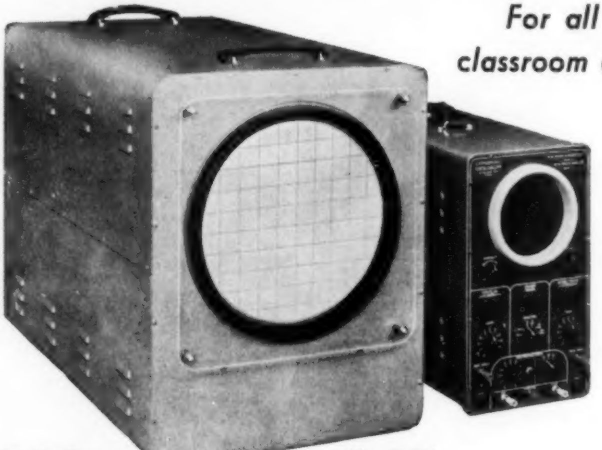

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